Transactions of the I·R·E

Professional Group on ELECTRONIC COMPUTERS

December, 1953

Volume EC-2 Number 4

TABLE OF CONTENTS

The Institute of Radio Engineers

IRE PROFESSIONAL GROUP ON ELECTRONIC COMPUTERS

The Professional Group on Electronic Computers is an association of IRE members with professional interest in the field of Electronic Computers. All IRE members are eligible for membership, and will receive all Group publications upon payment of the prescribed assessment.

1953 Assessment: $2.00

• • •

Transactions of the I•R•E®

Professional Group on Electronic Computers

Published by the Institute of Radio Engineers, Inc., for the Professional Group on Electronic Computers at 1 East 79th Street, New York 21, N. Y. Responsibility for the contents rests upon the authors and not upon the Institute, the Group, or its Members. Extra copies of this issue are available for sale to IRE-PGEC members at $1.25; to other IRE members at $1.85; and to nonmembers at $3.75. Address requests to The Institute of Radio Engineers, 1 East 79th Street, New York 21, N. Y.

Notice to Authors: Address all papers and editorial correspondence to W. Buchholz, IBM Engineering Laboratory, Box 390, Poughkeepsie, N. Y. To avoid delay, 3 copies of papers and figures should be submitted, together with the originals of the figures which will be returned on request. All material will be returned if a paper is not accepted.

EDITORIAL

This issue marks the end of the first year of regular uarterly publication. Judging from the interest shown by eaders and contributors, it appears that the PGEC RANSACTIONS are now a going concern. The Editorial oard and the PGEC Publications Committee will, of ourse, continue to try to improve the TRANSACTIONS nd the services it can offer to its readers. We hope to eceive suggestions and comments, and we want to repeat hat we will publish both technical and non-technical etters to the Editor.

As a result of a number of questions concerning omputer terms and definitions, we have asked Nathaniel ochester and Willis H. Ware to write a guest editorial or this issue. The authors, who have been active in this ork for a number of years, are the chairmen of the two RE Subcommittees which deal with computer terminology. o compile an industry-wide list of standard terms and efinitions is a considerably tougher job than may appear t first sight, and the two subcommittees, in the eastern nd western parts of the country, are doing an excellent ob to reconcile differences of opinion and usage. The esult, a revision of the IRE standard list of computer erms published in March 1951, will appear in due course. In the meantime, we hope that the authors' comments will deter those whose impatience or inexperience in such work might otherwise lead them to attempt a hasty duplication of effort. Publishing an inadequate list of terms would only confuse people who are new to the computer field.

The special Computer Issue of the PROCEEDINGS of the I.R.E. (October, 1953) was very successful, more so perhaps than the Publications Committee at first anticipated. The contributions of the PGEC were recognized in the Acknowledgments of that issue, although most of the credit really belongs to the many contributors. But we regret that in the last-minute rush it was neglected to mention specifically J. H. Felker and J. R. Weiner who spent a great deal of their time on the selection of the material. Nor was there any mention of the hardest part of the work, done by E. K. Gannett, the Administrative Editor, and his staff at IRE Headquarters, under the guidance of Dr. A. N. Goldsmith, the Editor of the PROCEEDINGS. Their work, done without the fanfare of publicity, covers not only the PROCEEDINGS but also the printing of the Professional Group TRANSACTIONS. The PGEC owes them a vote of thanks.

NOTICE TO PROSPECTIVE SPEAKERS

The meetings Committee of the PGEC receives reuests for computer papers to be presented at various eetings throughout the country. Accordingly, it is atempting to assemble prospective papers on different opics in this field so that it can fulfill these requests.

If you have such a paper please mail a comprehensive abstract to W. L. Martin, Chairman Meetings Committee, Telecomputing Corporation, 133 East Santa Anita Avenue, Burbank, California. Should your paper be selected, the request to present it will come directly from the program chairman of the meeting for which it has been chosen.

COMPUTER DEFINITIONS

(Guest Editorial)

Nathaniel Rochester
Willis H. Ware
Chairmen of Eastern and Western
Definitions Subcommittees of the
Electronic Computers Committee

In a rapidly changing field like computer engineering today, there is a rapid growth of language. One source of new terminology is the naming of newly invented devices. Even more new terms arise as laboratory slang gradually becomes acceptable for formal use. In only a few years the language changes so much that one would need an interpreter if he did not keep up to date.

This growth of language tends to produce confusion because inconsistent or even contradictory usages arise as local dialects. The same developments take place independently in different laboratories and different names are used for similar things. This makes it difficult to write a technical paper or a specification so that everyone can understand it. Therefore, the IRE has technical committees which, among other things, produce glossaries indicating conventional usage of terms.

The first IRE glossary of computer terms was published in the March 1951 PROCEEDINGS. This glossary was the result of committee work which began early in 1948. Most of the detailed work was done during the winter of 1949-50 when the definitions subcommittee met once a month. During the latter part of 1950 the work of the subcommittee was reviewed and approved, first by the Electronic Computers Committee and then by the Standards Committee.

In the preparation of this glossary, there was no intention to dictate what language people should use. Instead the policy of other compilers of dictionaries was used. The intent was to record usage, considering both the extent of usage and just who uses certain terms in certain ways. To illustrate the latter point, the term "ain't" does not appear in our copies of Webster and is considered poor even though many people use it frequently. The policy of recording usage appears to be the only way to aid in eliminating dialects without stifling progress.

There are also the problems of contradictory and erroneous usage. For an example of contradictory usage, consider "Flip-Flop" which in this country refers to a device with two stable states and in at least some parts of England refers to a device with one stable state. Sometimes erroneous usage arises when a person will start using a term in a certain way because he actually does not understand the phenomenon of which he speaks. Definitions subcommittees deal with these questions as individual problems to be settled usually by some compromise but sometimes by recognizing only one side of the controversy. Fortunately, there are not many such problems.

Early in 1952 it was decided to revise the existing glossary. Two subcommittees were appointed to deal with the problem. One of these subcommittees meets in New York and the other meets in Los Angeles, so as to be able to record the language on both sides of the mountains. The two committees are working together to produce a single final glossary.

In order to function as effectively as possible, the members of these committees were drawn from a variety of industrial, governmental and academic organizations. The first act of the committees was to write to all known English speaking computer organizations, enclosing a copy of the printed standard and asking for comments. The results of this survey are being carefully considered as the final list develops. The members of these committees do not act as agents of their own organizations to argue for their own terminology. Instead they cooperate as members of the committee, and seek to do a good job of lexicography.

It is hoped that the subcommittee work will be complete by the spring of 1954 and that the new glossary can be published within a year of that time. People who have not participated in definitions work may be surprised that it takes so long. The basic reason is that it is nearly impossible for one individual to write a definition so well that a critical review by several others with differing backgrounds will not reveal some vital defect. Since no one person is familiar with enough different usages, the only safe procedure is group discussion. For those who are impatient, we can say only that there will not be too many really drastic revisions of the 1951 glossary.

In closing, let us point out a knotty problem facing any definitions committee. It seems to be impossible to write any one definition of any one term which will be completely acceptable to everybody. You will read some definition and feel that you would like it a little better if it were a little different. When you do, remember that there probably is someone, whom you do not know, who would find that your little change would make the definition useless to him. The finished definition of the committee is phrased to meet, as nearly as possible, the requirements of all known users.

SOLUTION OF LINEAR DIFFERENTIAL EQUATIONS WITH VARIABLE COEFFICIENTS BY THE ELECTRONIC DIFFERENTIAL ANALYZER

Carl E. Howe
Oberlin College
Oberlin, Ohio

and

Robert M. Howe
University of Michigan
Ann Arbor, Michigan

SUMMARY – A relay device is described which varies resistance in a stepwise continuous manner in order to approximate arbitrary functions of time. The device can be used with electronic differential analyzers to solve linear differential equations with variable coefficients. Sample solutions of Bessel's equation are included as examples. Calibration and measurement techniques which permit computer accuracies of several hundredths of a percent are discussed.

I INTRODUCTION

The electronic differential analyzer is becoming one of the most widely used and versatile computers. It is, however, limited to the solution of ordinary differential equations since it can integrate with respect to only one independent variable, time. On the other hand, many of the equations which the engineer needs to solve are partial differential equations; that is, they involve rates of change with respect to more than one independent variable. If a partial differential equation is linear, it can often be converted by separation of variables to ordinary differential equations of the eigenvalue type. For example, the equation describing the dynamic deflection of an aircraft wing is a partial differential equation, second order in time, fourth order in spanwise distance along the wing. By assuming that the vibration is a pure harmonic, we can eliminate time from the equation and obtain a fourth-order linear ordinary differential equation, where distance along the wing is the independent variable. If we wish to solve this equation with the electronic differential analyzer, time on the analyzer will correspond to distance along the wing. Coefficients representing the flexural rigidity and mass per unit length of the wing appear in the differential equation and in general will be functions of distance along the wing. Thus the analyzer is called upon to solve a differential equation with coefficients which are a known function of time.

Another example of a physical problem involving ordinary linear differential equations with time-varying coefficients is found in the equations describing the trajectory of a rocket. These equations contain coefficients representing the rocket mass, which may vary in known manner with time as the fuel is consumed.

II THEORY OF THE ANALYZER

The theory of operation of the electronic differential analyzer has been well described in the literature.[1,2,3] We remind the reader that the fundamental component of such a computer is the operational amplifier, shown schematically in Fig. 1. It consists of a high-gain dc amplifier along with several input impedances, Z_a, Z_b,

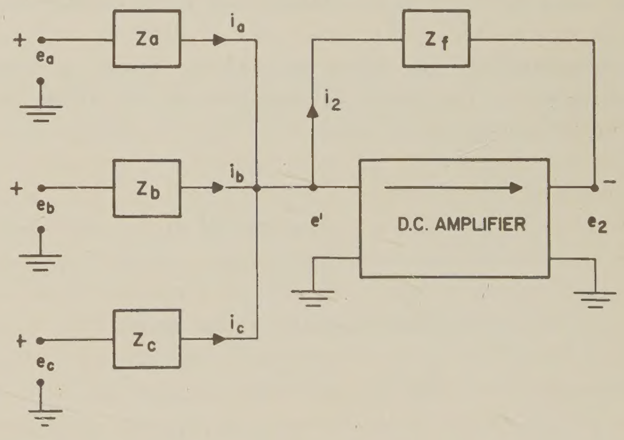


Fig. 1 – Operational Amplifier.

1. Hagelbarger, Howe and Howe, *Investigation of the Utility of an Electronic Analog Computer in Engineering Problems*, University of Michigan, Engineering Research Institute, External Memorandum UMM-28, April, 1949.
2. Howe, Howe and Rauch, *Application of the Electronic Differential Analyzer to the Oscillation of Beams, Including Shear and Rotary Inertia*, University of Michigan, Engineering Research Institute, External Memorandum UMM-67, January, 1951.
3. Korn and Korn, *Electronic Analog Computers*, McGraw-Hill, New York, N. Y.

and Z_c, and a feedback impedance, Z_f. It is easy to show that if the gain of the amplifier is very much greater than the ratio of feedback to input impedance, then

$$e_2 = -\left[\frac{Z_f}{Z_a} e_a + \frac{Z_f}{Z_b} e_b + \frac{Z_f}{Z_c} e_c\right] \qquad (1)$$

where e_a, e_b, and e_c represent input voltages and e_2 is the output voltage. If the feedback and input impedances are resistors, then the input voltages can be multiplied by any desired constant and summed to give the output voltage. If an input impedance is a resistor R and the feedback impedance is a capacitor C, then the output voltage e_2 is equal to $-1/RC$ times the time integral of the input voltage. Evidently, by employing fixed resistors and capacitors, operational amplifiers can be used for multiplication by a constant, summation, sign reversal and integration. These properties are all that are needed to solve ordinary linear differential equations with constant coefficients.

If, on the other hand, some of the coefficients in the differential equation are not constant but are time-varying, (i.e. functions of the independent variable) then it becomes necessary to multiply the voltages representing the appropriate dependent variables by the known functions of time. Suppose, for example, that we wish to multiply a voltage e_1 by a known time function $f(t)$. The usual method is to apply e_1 to a potentiometer, the movable contact of which varies as $f(t)$. The voltage of the movable contact will be $f(t)e_1$ provided that the load resistance into which the potentiometer works is very large compared with the resistance of the potentiometer itself.

A somewhat more direct method for obtaining $f(t)e_1$ is to apply e_1 to the operational amplifier shown in Fig. 2, where the input resistor R is fixed and the feedback resistor varies with time as $f(t)R$. The output voltage of the amplifier will then be (except for a sign reversal) $f(t)e_1$ as required. By varying the input resistor as $Rf(t)$ and making the feedback a fixed resistor R, the input voltage can be divided by $f(t)$. The variation of input and feedback resistors directly in an operational amplifier has the advantage of not introducing any potentiometer-loading error.

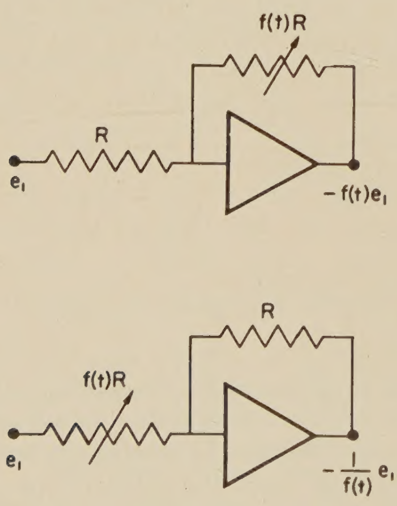


Fig. 2 — Operational Amplifier with Variable Gain.

III DESCRIPTION OF THE BINARY DIGITAL COEFFICIENT CHANGER

Instead of changing the input resistors continuously with time, the authors have had considerable success with a relay device which varies the resistance in discrete steps. Thus the function $f(t)$ in Fig. 3 is represented by the step approximation shown. After each interval of time Δt the resistance is switched to a new value. The resistance of each step approximation is chosen so that at the end of the interval the area under the step curve equals that under the continuous curve. The resistance for each step is obtained by building it up from a set of binary resistors connected in series.

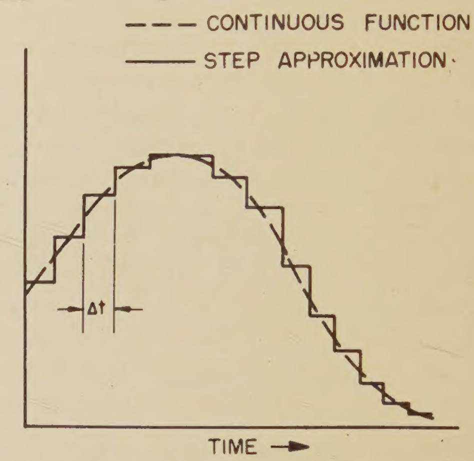


Fig. 3 — Step Method of Approximating a Function.

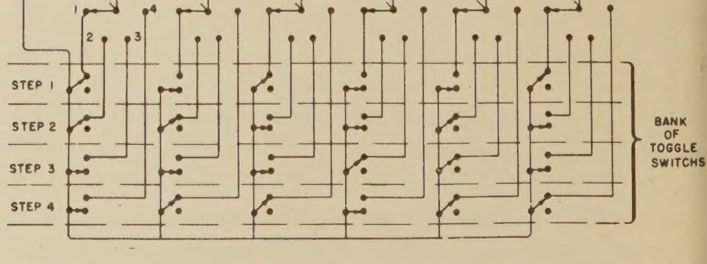


Fig. 4 — Binary Digital Circuit for Varying Resistance.

Consider the set of binary resistors shown at the top of Fig. 4. Evidently the total resistance R can be made anything from zero ohms to 63 k ohms in 1 k-ohm steps

by short-circuiting the appropriate binary resistors with their respective relays. The relays for each binary resistor are in turn controlled by the rows of toggle switches at the bottom of Fig. 4. Finally, a stepping relay selects just which row of toggle switches controls the binary-resistor relays. As the stepping relay moves from one rotary position to the next every Δt seconds, it switches control from one row of toggle switches to the next. By properly positioning the toggle switches ahead of time, any desired set of binary resistors can be switched in on each step.

In the example shown in Fig. 4 the first row (step 1) of toggle switches is up, down, up, down, down, up, from left to right. When the stepping relay is on step 1, therefore, the binary relays short-circuit the 16, 4 and 2 k-ohm resistors, leaving the total resistance R for step 1 as $R = 32 + 8 + 1 = 41$ k ohms. For step 2 the toggle switches are up, up, down, down, up, down, so that when the stepping relay rotates to step 2, the resistance $R = 32 + 16 + 2 = 50$ k ohms. As the stepping relay proceeds to step 3 and step 4 the resistance R changes in accordance with the positions of the toggle switches in rows 3 and 4 respectively. Evidently any step-wise continuous function of resistance such as that shown in Fig. 2 can be obtained by properly positioning ahead of time the toggle switches at each step (i.e. in each row). Note that the same set of binary resistors is used over and over again.

For purposes of illustration the circuit shown in Fig. 4 has provision for only 6 digits and 4 steps in time. The actual equipment in use by the authors has provision for 25 digits and 25 steps (see Fig. 5). The

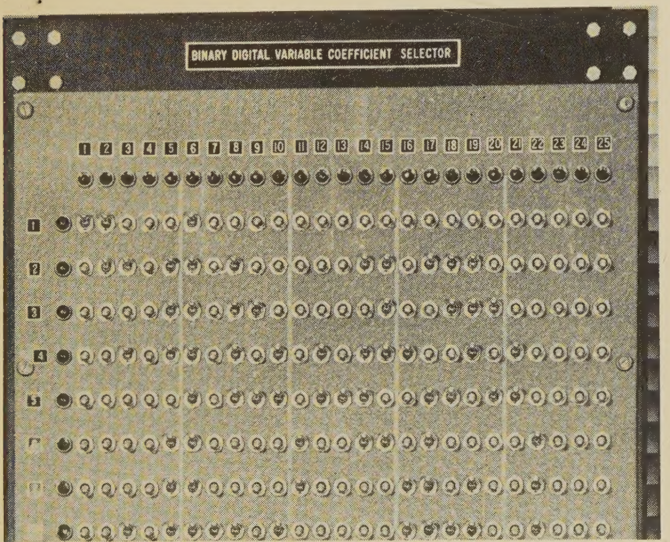


Fig. 5 – Binary Digital Coefficient Changer.

binary resistors are plug-in units, so that the 25 available digits can be divided between two or more functions. If a function $f(t)$ changes sign, a digit may be used to switch in an inverting amplifier at the proper time. The stepping relay is driven by pulses obtained from a 100 kc secondary frequency standard. The 100 kc signal is stepped down to 1, 2, 2.5, or 5 pulses per second by means of multivibrator circuits. When a button is pressed to start a solution on the electronic differential analyzer, the stepping relay moves from a standby step 26 to step 1 and simultaneously releases the initial conditions on all the integrating amplifiers. When the stepping relay has gone through all the steps and returns to 26, it automatically stops itself and restores the initial conditions.

The stepping-relay scheme for approximating variable coefficients has a number of important advantages. (1) Any function of time can be set up in a few minutes, merely by setting the toggle switches properly to represent the function at each interval. (2) Functions which may change magnitude by large factors can readily be handled without loss of absolute accuracy (resistances which change by factors of 1000 or more have been set in). (3) The repeatability of the time-varying resistance from one run to the next is excellent. This is extremely important in solving many eigenvalue problems, where changes in analyzer components or initial conditions of the order of 0.01 percent may make it impossible to converge on a correct solution. (4) Any arbitrary input function for a non-homogeneous equation can be simulated as a step-function approximation. If a smoother approximation is desired, the derivative of the input function can be set in and integrated once to give a series of straight-line approximations, which should be adequate for most purposes. (5) Variable resistors which may be fairly large (as much as 20 megohms or more) may be handled.

IV

EXAMPLES OF THE STEPPING-RELAY METHOD FOR SOLUTION OF LINEAR DIFFERENTIAL EQUATIONS

In order to check the accuracy of the step approximation for variable coefficients, it was decided to solve several classical equations with known solutions. Consider, for example, Bessel's equation,

$$\frac{d^2y}{dx_2} + \frac{1}{x}\frac{dy}{dx} + \left(1 - \frac{n^2}{x^2}\right) y = 0, \qquad (2)$$

which can be rewritten as

$$x\left(\frac{d^2y}{dx^2} + y\right) = -\frac{dy}{dx} + \frac{n^2}{x}\, y \qquad (3)$$

The electronic differential analyzer circuit for solving this equation is shown in Fig. 6. Note that the time constant of the integrators is 2 seconds, so that one unit in x equals 2 seconds. The two time-variable resistors are approximated by the stepping-relay scheme described in the previous section. Five binary digits are required to simulate the linear resistance in 25 steps.

By using hold relays to disconnect the input resistors of the integrators x_o time units after a solution has begun, the integration can be stopped and the integrator outputs held fixed at their x_o value. The output voltages representing y and dy/dx can then be read with a potentiometer to high precision. A digit of the stepping-relay panel is utilized to energize the hold-relays at the desired time x_o after the solution has begun. For example, if the stepping relays are operated at four steps per unit x (two steps per second for the circuit of Fig. 6), then the integration can be stopped at $x = 0.25$, 0.50, 0.75, etc., and the dependent variable y measured with high precision at each of these x values. After any single y measurement obtained in this manner for a given x, the solution is restarted from $x = 0$ to obtain a y measurement for a different x.

With the above technique a point by point tabulation of the electronic-differential-analyzer solution can be

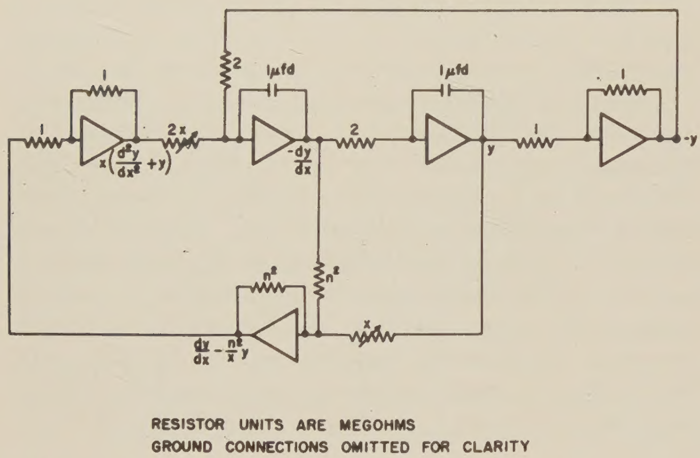


Fig. 6 — Analyzer Circuit for Bessel's Equation.

made to four or five significant figures. In order to compare the analyzer solutions using the step approximation with the theoretical solutions, such a tabulation was made for a Bessel Function J_o of the first kind ($n = O$). The results for 2, 4, and 10 steps per unit x are shown in the table below.

ERROR IN ANALYZER SOLUTION

J_O (THEORETICAL) – J_O (ANALYZER)

X	THEORETICAL J_O	TWO STEPS PER UNIT X	FOUR STEPS PER UNIT X	TEN STEPS PER UNIT X
0.0	1.0000	0.0000	0.0000	0.0000 (Preset)
0.5	0.9385	0.0090	0.0007	0.0000
1.0	0.7652	0.0012	−0.0016	−0.0007
1.5	0.5118	−0.0053	−0.0033	−0.0010
2.0	0.2235	−0.0095	−0.0042	−0.0016
2.5	−0.0484	−0.0108	−0.0034	
3.0	−0.2607	−0.0104	−0.0028	
3.5	−0.3801	−0.0066	−0.0009	
4.0	−0.3971	−0.0027	0.0004	
4.5	−0.3205	0.0016	0.0016	
5.0	−0.1776	0.0048	0.0020	
5.5	−0.0068	0.0069	0.0023	
6.0	0.1506	0.0070	0.0018	

The initial condition $y(O)$ set on the analyzer for the above solution was approximately 80 volts. Voltages were measured with a Leeds and Northrup Type K-2 Potentiometer. The results in the table are subject to a slight correction as a result of a 2 millesecond delay in the hold-relay operation. This correction would lessen the analyzer errors shown, by from 0.0000 to 0.0010, depending on the slope of the solution. Evidently the analyzer solution for J_o obtained by using the step-approximation to the variable coefficient exhibits a maximum error of about 1.0 percent of the maximum amplitude for two steps/unit x and about 0.1 percent for ten steps/unit x.

Analyzer solutions of $J_{1/2}$, J_1, and J_3 ($n = 1/2$, 1 and 3 in Eq. (2) are shown in Fig. 7. For the theoretical $J_{1/2}$ function the initial displacement is zero, but the initial slope is infinite. This is approximated by a large, but finite initial condition on $\frac{dy}{dx}$ for the analyzer. Despite

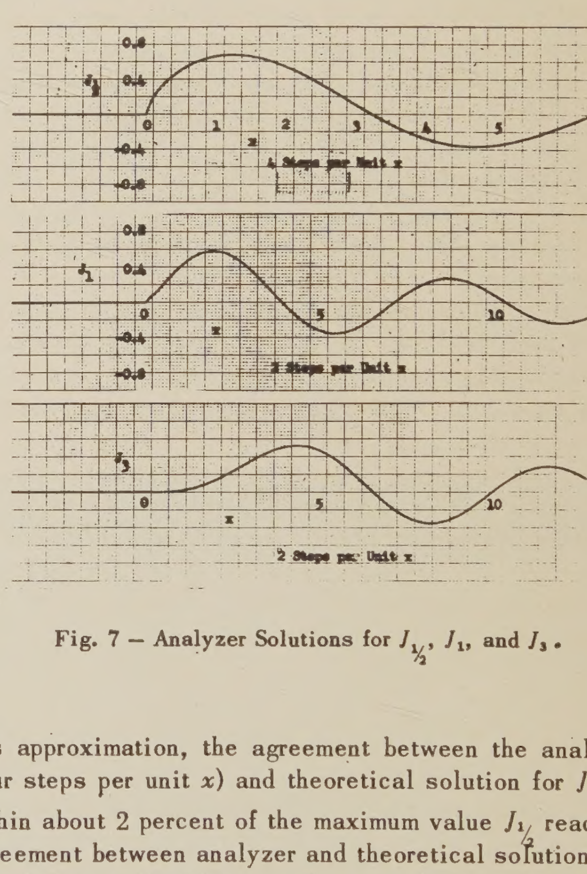


Fig. 7 — Analyzer Solutions for $J_{1/2}$, J_1, and J_3.

this approximation, the agreement between the analyzer (four steps per unit x) and theoretical solution for $J_{1/2}$ is within about 2 percent of the maximum value $J_{1/2}$ reaches. Agreement between analyzer and theoretical solutions for J_1 and J_3 is well within recorder error (one percent). Note that the J_3 function starts with zero initial displacement and slope. The solution is generated by the computer because the system has a negative "spring constant" and is unstable for 6 seconds after the beginning of the solution. Any small initial unbalance in the computer amplifiers causes the finite solution to be generated. The amplitude of the solution cannot be selected ahead of time and may even reverse sign from one run to the next, but the shape of the solution always agrees accurately with the theoretical solution. This is demonstrated

by the following table, which compares the roots from the analyzer solution for J_5 with the theoretical roots:

ROOT NUMBER	ANALYZER ROOT	THEORETICAL ROOT
1	8.76	8.78
2	12.34	12.34
3	15.68	15.68
4	18.96	18.96
5	22.18	22.22
6	25.40	25.40
7	28.61	28.63
8	31.78	31.81
9	34.93	34.98

The stepping relays were operated at one step per unit x for the above solution of J_5.

The step method of approximating variable coefficients has been utilized by the authors to solve a wide variety of problems,[1,2,4,5] including Legendre's Equation, vibration of non-uniform beams, heat conduction through non-uniform media, flow of viscous fluids through pipes, wave propagation through non-uniform media, etc. In every case where a theoretical solution was available, the analyzer solution proved to be surprisingly accurate.

V CALIBRATION AND MEASUREMENT TECHNIQUES

The accuracy of the electronic differential analyzer can be only as good as the accuracy of the resistor and capacitor components, and with this thought in mind the authors have devised a method of calibrating integrators to considerable accuracy. The measurement of resistor values using bridge methods and high-precision standards is straightforward and will not be described here. To measure the values of feedback capacitors on integrators, three operational amplifiers are set up to solve the equation of simple harmonic motion, as shown in Fig. 8. If the input and feedback resistors R for the inverting amplifier are matched to a high precision, then the equation solved by the analyzer is

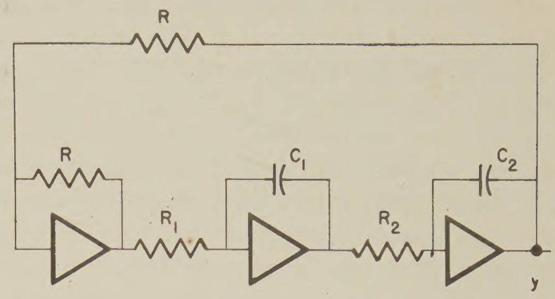
$$R_1 R_2 C_1 C_2 \frac{d^2y}{dt^2} + y = O, \tag{4}$$

and the angular frequency ω of the sinusoidal solution is

$$\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}} \tag{5}$$

4. Howe, Howe, and Rauch, *Solution of Linear Differential Equations with Time-varying Coefficients by the Electronic Differential Analyzer.* Paper No. 15. pp. 89-97, Project Cyclone, Symposium II on Simulation and Computing Techniques, Part 2. Reeves Instrument Corporation.
5. R. M. Howe, *Propagation of Underwater Sound in a Bilinear Velocity Gradient,* University of Michigan, Engineering Research Institute, External Memorandum AIR-3. Office of Naval Research Contract N6 ONR 23223, (Project 2002).

The fundamental period T corresponding to the frequency ω is measured by observing the time taken for a number



$$R_1 R_2 C_1 C_2 \frac{d^2y}{dt^2} + y = 0$$

$$\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

Fig. 8 — Analyzer Circuit for Calibration of Capacitors.

of oscillations. Tenth-second timing pulses a 100 *kc* secondary frequency standard are recorded along with the sinusoidal oscillation to provide an accurate time reference. If we denote the measured period of sinusoidal oscillation as T_{12} for capacitors C_1 and C_2 in the circuit, then we will measure a different period T_{13} for capacitors C_1 and C_3, and still a different period T_{23} for capacitors C_2 and C_3. Having measured the resistors R_1 and R_2 accurately, we can calculate C_1, C_2, and C_3 to a high precision. For example, suppose R_1 and R_2 differ very little from an integral resistor R and C_1, and C_2, and C_3 differ very little from an integral capacity C. Then we can write

$$R_1 = (1 + r_1)R \qquad C_1 = (1 + c_1)C$$
$$R_2 = (1 + r_2)R \qquad C_2 = (1 + c_2)C$$
$$C_3 = (1 + c_3)C$$

Also let

$$\epsilon_{12} = \frac{T_{12}}{2\pi RC} - 1$$

$$\epsilon_{13} = \frac{T_{13}}{2\pi RC} - 1$$

$$\epsilon_{23} = \frac{T_{23}}{2\pi RC} - 1$$

Then it can be shown that to a high degree of approximation

$$C_1 = (1 + c_1)C = \left[1 + \epsilon_{12} + \epsilon_{13} - \epsilon_{23} - \frac{(r_1 + r_2)}{2} \right] C$$

$$C_2 = (1 + c_2)C = \left[1 + \epsilon_{12} + \epsilon_{23} - \epsilon_{13} - \frac{(r_1 + r_2)}{2} \right] C$$

$$C_3 = (1 + c_3)C = \left[1 + \epsilon_{13} + \epsilon_{23} - \epsilon_{12} - \frac{(r_1 + r_2)}{2} \right] C$$

From the observed deviations ϵ_{12}, ϵ_{13}, and ϵ_{23} of $T/2\pi RC$ from unity and the known values of r_1 and r_2, the capacitor values C_1, C_2, and C_3 can be determined.

Having measured the feedback capacitors in this manner, it is possible to match input resistors to obtain a desired RC product with an accuracy of 0.01 percent. Cognizance must, of course, be made of the fact that the RC product is somewhat temperature sensitive. Using these calibration techniques, the authors have solved eigenvalue problems with the electronic differential analyzer to accuracies of the order of hundredths of a percent. With the hold-relay method of tabulation which was described in Section III, solutions having accuracies of this order of magnitude can conveniently be recorded.

AUTOMATIC BEAM CURRENT STABILIZATION FOR WILLIAMS TUBE MEMORIES

Rudolph J. Klein
Oak Ridge National Laboratory
Oak Ridge, Tennessee

SUMMARY — **One difficulty encountered in the operation of the Williams type electrostatic memory is the critical nature of the storage tube beam current. Ordinarily, frequent adjustment is required to maintain this parameter within the reliable operating region. By the use of a simple circuit the adjustment may be made automatically resulting in increased reliability and ease of operation.**

With the Williams type electrostatic memory, information is stored in the form of charge patterns on the screen of a cathode ray tube. A certain distribution of charge is used to represent a binary "1", and another distribution to represent a binary "0". These patterns are established with an electron beam of a certain intensity and are interrogated with the same beam. Upon inspection of a storage location with this beam, the charge pattern is changed, and this change is capacitively coupled to a pickup plate which is fastened to the tube face. After suitable amplification, the pulse is amplitude gated to determine which charge pattern existed prior to interrogation. This information is usually stored in a toggle and later used to restore the charge pattern to its original state. It may also be transferred from this toggle to the arithmetic section of the computer.

The amplitude of the pulse resulting from the inspection of a storage location is then the important consideration. This amplitude may be affected by a number of factors:

1. Small imperfections on the storage screen produce abnormally small pulse output.
2. Spill from interrogation of one storage location may produce abnormally large pulse output at surrounding locations.
3. Changes in amplifier gain may either increase or decrease pulse output from all locations.
4. Changes in beam current may either increase or decrease pulse output from all locations.

With a certain cathode ray tube, very little can be done about the first two causes of pulse irregularity. It is therefore desirable to adjust the amplitude discriminator to minimize the effect of them. This requires that the remaining two causes of pulse output variation be accurately controlled.

The third cause, amplifier gain drift, can be minimized by the use of feedback within the amplifier itself. However, the fourth cause, changes in storage tube beam current, is more troublesome.

Several things tend to alter the beam current once it is adjusted. The most frequently encountered are:

1. The optimum operating current is usually very small compared with the currents for which ordinary cathode ray tubes are designed. Currents in the order of 1 microampere are normally used with Williams storage, whereas approximately 100 times this current is required to produce usable light output. An abnormally large bias voltage must therefore be applied to the control grid of the storage tube, thus allowing only the electrons with the highest initial energy to pass. Small changes in filament temperature therefore cause sizable beam current changes for a given bias in this region. On some tubes a 10% filament voltage change caused as much as 75% change in output pulse amplitude.
2. The control grid aperture is located very close to the cathode in most cathode ray tubes. Any small change in gun temperature will alter this spacing and thus affect the grid-to-cathode field, which in turn changes the beam current. This effect is

quite severe on some of the smaller tubes, and is still objectionable on the 5-inch tubes.

3. The bias voltage required for correct beam current (usually in the order of 40 to 100 volts for most commercial tubes) is usually derived from a series of resistors and potentiometers which form a bleeder on the high voltage power supply. This bias is then subject to drift due to changes in resistor temperature and supply voltage. With the 3JP1 cathode ray tube and an amplifier gain of 35,000, the gain from CRT bias to "1" signal output is about 15; i.e., if the bias changes 1 volt, the amplifier output pulse for a "1" will change 15 volts. The desired "1" signal is usually in the order of 20V. so as little as 1 percent change of CRT bias could produce a 75 percent change in output signal amplitude.

These factors act to alter the amplitude of the output signals from all storage locations on the cathode ray tube so that frequent readjustment is necessary to hold the beam current within a usable region.

SYSTEM

The automatic beam current stabilizing (ABS) system to be described was developed for use with the Oak Ridge National Laboratory's 40 digit binary computer, ORACLE. It will compensate for the previously mentioned drifts and also for amplifier gain changes up to about 25 percent.

The principle of this system involves the use of one storage location as a test point. The circuit is designed to sample the output of this location periodically and adjust the beam current to keep this output at a constant amplitude. All the other storage locations on the tube use the same beam current and amplifier system, so their outputs are also free of amplitude drift. The apparent disadvantage of having one memory location used up as a test spot is not as severe as it might appear. In almost every computation of sufficient length to require the full memory capacity, it is necessary to have a constant of the same value as this test number stored in the memory, so that the test location can serve a dual purpose.

It is possible to use either the negative going or dot output ("O") or the positive going or dash output ("1") to provide the sampling signal. However, the positive going signal was chosen, since it is 5 to 10 times more sensitive to beam current variation than the negative signal.

There is a possibility that the test location will not contain the desired charge if a location near by has been interrogated several times. The spill electrons from this nearby spot would produce an abnormally large positive signal output from the test location, even if the beam current were correct. To prevent a false indication of this kind, the test location is restored to standard conditions immediately before sampling by arranging the control circuit to write a fresh "one" charge pattern just prior to sampling.

The ABS circuit requires one minor memory cycle or 20 μS to restore the test spot to standard conditions and another cycle to sample it, or 40 μS total. The occurence of these ABS cycles is timed by a free running multivibrator operating with a period of about 20,000 μS. This allows the sampling pulses to occur at regular intervals and keeps a constant duty cycle on the sampling circuits.

The use of ABS with the ORACLE memory is complicated slightly by the use of two separate cathode ray tubes for each digit to allow cancellation of screen impurities. The tubes are interrogated using a time multiplex system to permit this "best of two" selection with a single amplifier channel. With this system, the amplitude information from the test location of each tube must be individually gated, stretched, and applied as a bias correction to the appropriate tube. This does not lengthen the 40 μS ABS cycle, however.

CIRCUIT

The circuit, Fig. 1, is arranged to compare the signals out of the amplifier with a reference voltage and produce a correction signal proportional to the difference. This comparison circuit (V_1) is normally disabled because of the large positive voltage applied to G_2 of V_1. During the sampling portion of the ABS cycle, G_2 is dropped to ground potential. The amplifier output is capacitively coupled to g_1 which is returned to a variable negative voltage. This negative voltage is the reference with which the sampled signals are compared. The result of the comparison appears as a positive signal out of plate P_2 of V_1. This narrow pulse is stretched to about 10 μS in V_2 and again stretched in V_3. The second stretching circuit has a time constant of 100 seconds which prevents applicable beam current change between sampling cycles.

The 100-second time constant contains a 1 μf storage condenser (C_1) which must be charged in a relatively short time. The usual low current bleeder on the HV system will not provide sufficient charging current by itself for this stretching circuit. However, the duty cycle is very small, so that a condenser (C_2) may be charged from the HV bleeder during the rest period to provide the current surge needed during the ABS cycle.

The grid of the second stretching stage is returned to the intensity potentiometer to allow the operating range of the circuit to be set at the most efficient point. This setting is not at all critical, as the ABS circuit will provide up to about 50 volts of corrective bias.

The output of this second stretching circuit is connected directly to the cathode of the cathode ray tube. The bias on the storage tube then increases if the sampled pulse is too large and vice versa.

The ABS gating signal applied to G_2 of V_1 must last

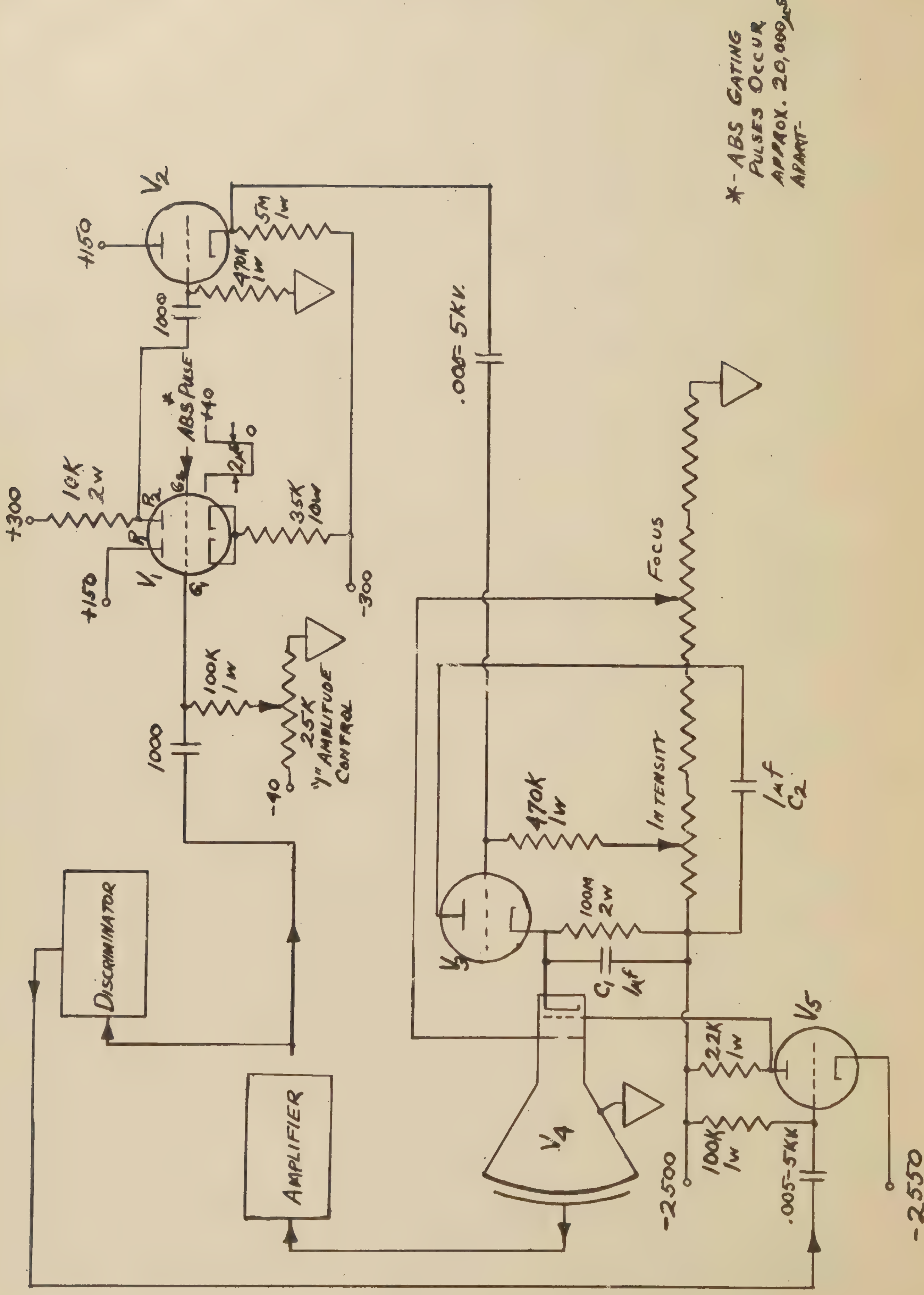


Fig. 1 – Beam Current Stabilizing Circuit.

ng enough to allow both the "one" signal itself and s "beam turn-off pulse" to pass, because when the ower is first applied to the memory, no storage tube bias s present, and therefore tremendous beam current is rthcoming. With this large beam current, the usual

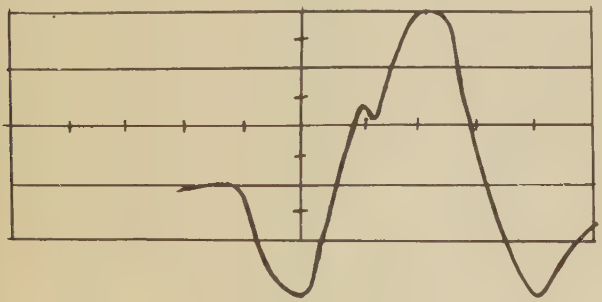


Fig. 2 – Beam Current Extremely High.

torage phenomenon does not occur, and the ordinary 'one" signal is not positive, but its "turn-off pulse" is ery positive (Fig. 2). Normally this "turn-off pulse" is mall compared to the "one" signal (Fig. 4). So if both ulses are allowed into the sampling circuit, continuous

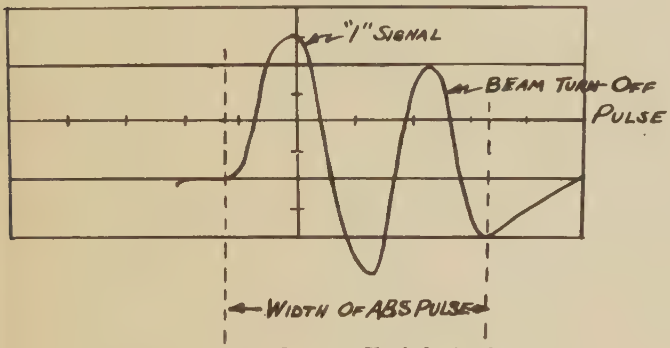


Fig. 3 – Beam Current Slightly High.

automatic control is provided over all bias ranges. When the power is first applied, the amplifier output is shown in Fig. 2. After a few ABS cycles, the output changes from Fig. 2 through Fig. 3 and finally stabilizes at Fig. 4, which is the normal operating condition.

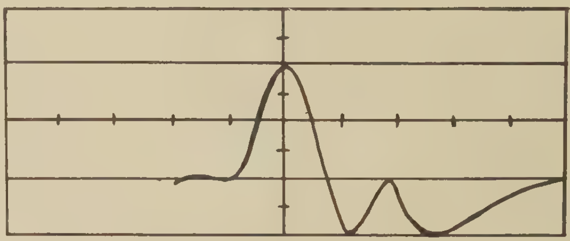


Fig. 4 – Normal Beam Current.
Note: Sweep Speed 2.4 μ S/CM
Vertical Sensitivity = 10 V/CM.
"1" Amplitude Control Set at 20 volts.

CONCLUSION

This ABS system has been in use on the ORACLE memory for about two months during the preliminary testing of the computer, and it seems to function quite satisfactorily. Practically no warm-up period is required for the memory, and intensity adjustments are rarely required. There is good indication that when the machine is put into service, the intensity controls will not ordinarily require attention after initial adjustments.

REFERENCE

F. C. Williams and T. Kilburn, "A storage system for use with binary digital computing machines", Proc. I.E.E., (London), Part II, Vol. 96; April 1949.

ACCURACY OF AN ANALOG COMPUTER

Lee Cahn
Beckman Instruments, Inc.
South Pasadena, California

SUMMARY – 1. To determine how accurate the computing components representing a given variable have to be, assume that they constitute one more piece of measuring equipment which must handle the data before it is fed into an ideal computer. 2. In general, the components of an analog computer must have individual accuracies consistent with the measuring equipment available to the group it belongs to. 3. The static accuracy of an operational amplifier may be measured simply by observing the grid voltage in a closed-loop connection as the output is swung through its full range at some low frequency (Fig. 2). Phase shift may be measured simply (Fig. 3), but usually does not play an important part in establishing limits of performance for the computer. 4. Integrator random drift may be measured simply, but is only one cause contributing to integrator error. Account should be taken of the grid deviations measured in the static test above, or else drift measured about a number of non-zero output levels. 5. The effect of integrator drift is to limit the computing time. Required computing time and highest required frequency are determined directly for real-time simulation. In other computing, one may be traded for the other, so long as the product R remains constant. R is the number of cycles of the highest frequency contained in the longest time. Two computers may be compared by comparing their R's; comparing drift rates, computing times, or maximum frequencies alone is not valid.

INTRODUCTION

This paper presents a practical method for determining the accuracy required of a general purpose electronic analog computer, a justification of the method, and a basis for evaluation of a computer.

REQUIRED ACCURACY

The method for determining how accurate a computer should be for a given problem is to consider each variable and coefficient in the problem individually. Generally, each quantity in the problem will have a tolerance, determined by the instruments with which it was measured, or by an engineering evaluation of how accurately it should be measured. This tolerance is basic to the study of the problem, and must be established, perhaps implicitly, regardless of whether a computer is used.

Within the computer it is generally possible to isolate the components which represent each problem quantity. They must then be consistent with the tolerance on that quantity. For example, let us consider an aircraft in the lateral mode.* The aerodynamic coefficient $C_1\phi$, relating the roll torque due to roll rate, to roll rate can be calculated roughly from the design data, or measured on a wind-tunnel model, or measured on a finished airplane. Typically, values derived by the latter two methods may differ by ± 10%. The wind-tunnel value is the result of an accurate measurement on an inaccurate model, while the flight-test value is the result of an inaccurate measurement on an accurate model.

We hope that the true value does not differ from a measured value more than the other measured value; that is, that the error in either measured value does not exceed ± 10%.

In the computer the coefficient $C_1\phi$ is represented by a potentiometer, an isolating resistor, a feedback resistor, and a summing amplifier (Fig. 1). Before the potentiometer the signal is ϕ, the roll rate ; after the summing amplifier it is $L\phi$, the roll torque. $C_1\phi$ appears nowhere else in the computer.

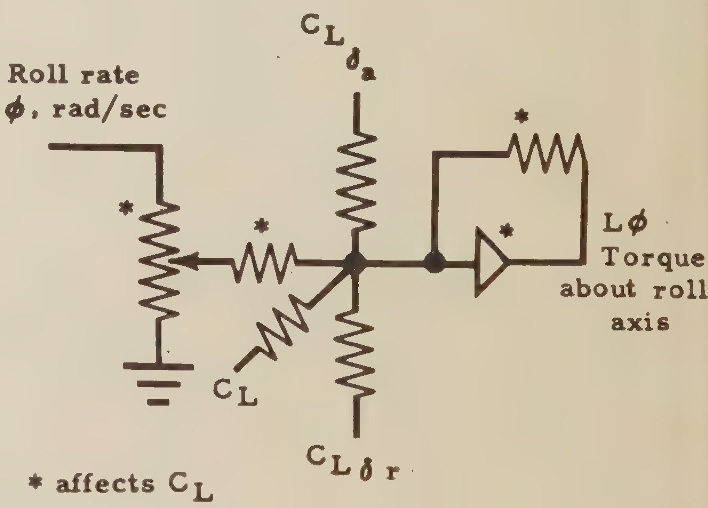


Fig. 1

Insofar as $C_1\phi$ is concerned, the computer airplane would be identical to the real airplane if the voltage gain through this circuit is equal to the true $C_1\phi$ (times the appropriate scaling coefficients). The computer response will be in error if the gain differs from $C_1\phi$. It does not make any difference in the computer response if the circuit gain varies from $C_1\phi$ because we do not know $C_1\phi$ correctly or if the gain varies from $C_1\phi$ because we do not know the gain correctly. The effect in computation is the same. Thus, we may evaluate the effect of computer component inaccuracy as if it were measuring instrument inaccuracy.

This does not mean that the $C_1\phi$ section of the computer can be in error by ± 10%, because it must be com-

*EASE Application Bulletin #2, Beckman Instruments, Inc., 2200 Wright Ave., Richmond, California, or C. D. Perkins and R. E. Hage, "Airplane Performance Stability and Control," John Wiley and Sons, New York, N.Y.; 1949.

bined with the more or less irremovable measuring error. However, let us remember that random errors should be combined as the square root of the sum of the squares. Thus, if the $C_1\phi$ section of the computer had a probable error of ± 10%, and the probable $C_1\phi$ measuring error were ± 10%, the probable error of true aircraft simulation would be $\sqrt{10^2 + 10^2} = 14\%$. Forty percent of the error would be due to the computer. If the computer error were 3%, the combined error would be 10.5%; only five percent of the combined error is due to the computer. It would then be more desirable to improve the accuracy of measurement from 10% to 9% than to go from a 3% computer to a perfect one. In this sense we should make sure that the computer accuracy is consistent with the accuracy of the measuring equipment. One goal is that we get the most favorable ratio of dollars cost per unit increase in accuracy.

Sometimes generalizations can be drawn from a large number of similar examples. Thus, most aircraft stability derivatives are known to the same order of accuracy. A computer intended primarily for aircraft control studies should then be required to be consistent, component by component, with that degree of accuracy. The same computer would be ill-suited to astronomical orbit calculations. If all the measuring instruments in a laboratory are ± 3%, that laboratory could justify ± 1% computing components, but ± 0.1% ones would be far-fetched.

Similar considerations apply to dynamic error.

Errors may also arise if the equations mechanized in the computer do not truly represent the physical system. In some applications this inaccuracy may exceed the measuring error. Since this fault is common to all analyses, whether hand or machine, it is not considered a computer error.

JUSTIFICATION

The computer is a dynamic system which closely resembles the real system being studied. So far we have been considering the differences between the computer system and the real system, as revealed by a series of separate measurements on each. It is probably more natural intuitively to consider the difference in the responses of the two systems. Comparison of responses is useful on occasional individual runs, as an overall check and in retrospective evaluation of a program which also included experimentation. It is not practical in general, because if one knew all real system responses already, he would not need a computer. Also, there is no unique value for the accuracy of computer solutions. The effect of fixed component errors on system response is different for each problem. A criterion of some value in this kind of comparison is the response of different computers to a standard problem, usually a three-amplifier oscillator. It does not seem practical to extrapolate results quantitively to problems of non-trivial complexity. It seems more desirable in a general purpose computer to use parameters which do not change from problem to problem. The only ones which do not are the individual components of the computer.

Philosophically, we may say either that we have a response which differs from that of the real system, or that we have an exact response of a system which differs from the real one. Both approaches seem valid, but the second one appears more useful in further analysis.

EVALUATION OF AN ELECTRONIC ANALOG COMPUTER

Every analog computer is a compromise between the conflicting requirements of cost, accuracy and convenience of operation. In designing a computer for high accuracy and convenience, cost skyrockets. For a given computer, cost is relatively fixed, but one can trade convenience of operation for accuracy every day to a different degree. Discussions of relative computer value must take this compromise into account.

The easiest part of a computer to evaluate is the part that sets the coefficients. Coefficients are primarily determined by potentiometers, resistors and capacitors, in electronic analog computers. The tolerances on these components are often given by their manufacturers, and can be measured by conventional methods. In initial design of a computer a compromise is reached between accuracy on one hand, and cost on the other. In certain types of operation 5% components may be adequate. Probably the most useful tolerance range is from 1% to 0.1%. Few applications actually require accuracies better than 1%. However, the difference in cost between 1% and 0.1% components is less than 10% of total computer cost. Cost rises steeply below 0.1%, and performance is limited by other factors. Some manufacturers will supply components of any requested available tolerance assembled in their computers.

Once the computer is built its effective accuracy still depends on a compromise with convenience. The nominal accuracy corresponds to the worst accuracy — the best convenience compromise, in which all components are assumed to have their nominal values. Effective accuracy can be improved over the nominal accuracy in several ways, all of which reduce operating ease. For example, one very accurate master pot can be used as a standard and all computing pots set by comparison with it. This method is not as convenient as setting each pot directly, but it can be quite a lot more accurate. It also can eliminate loading corrections. Then the convenience can be improved markedly by certain switching circuits, at the expense of a little more cost. Alternatively, each component may be calibrated once for all and the calibrated value used instead of the nominal.

In evaluating a computer for one's own purposes, one does not want to have to depend on the above artifices on every problem, for this is wasteful of operating time, nor does one want to spend so much initially that these artifices are never needed, for then he will be

paying dearly to save a little operating time on the few most accurate problems.

Another factor to be weighed is the frequency of setting of the pots. If they are set once for each problem, the labor of calibrating is not appreciable. If they are set several times a day, as in multishift operation, the setting time may be a big part of the operating time. In this case several computers which can remain set up may be preferable to one operated on three shifts. Perhaps some day an optimum can be calculated using, no doubt, an electronic computer. A point of some interest is that not all ±0.5% pots are in error by ± 0.5%, and that all pots do not err by the maximum amount over all of their range. A statistical the-ry is needed to determine the probable error in any setting, given the conventional tolerances of the components. Until it is derived, engineers will no doubt continue to use the rule of thumb that the median or "probable" error is about 1/5 the square root of the sum of the squares of the individual tolerances concerned. This is equivalent to setting the nominal tolerances at the 3σ limits, which may be done intentionally by some quality control groups. For example, if we used a 0.5% pot, and 1% input and feedback resistors, the *median* error would be

$$1/5 \sqrt{(1/2^2 + (1)^2 + (1)^2} = 0.3\%.$$

An effect equivalent to computing component inaccuracy can arise from operational amplifiers used for amplification. Their grid voltage and current are assumed zero in ordinary usage, so that

$$\frac{E_{in}}{Z_{in}} = -\frac{E_{out}}{Z_{out}}$$

However, the voltage from grid to ground will differ minutely from zero, principally due to two causes. First, many amplifiers do not have truly infinite open-loop gain, and some grid voltage is required to have the desired output. If the amplifier is not perfectly linear, there will be some curvature to the grid voltage in output voltage characteristic, equivalent to a variation in gain. Secondly, there may be a grid voltage offset due to drift.

If there is a non-zero grid voltage e_g, then

$$\frac{E_{in} - e_g}{Z_{in}} = -\left[\frac{E_{out} - e_g}{Z_{out}}\right]$$

Let ΔE_o = error in E_{out} due to e_g

$$\frac{e_g}{Z_{in}} + \frac{e_g}{Z_{out}} = \frac{\Delta E_o}{Z_{out}}$$

$$e_g \left[\frac{Z_{out}}{Z_{in}} + \frac{Z_{in}}{Z_{out}}\right] = \frac{\Delta E_o}{Z_{out}}$$

$$\Delta E_o = e_g \left[\frac{Z_o}{Z_i} + 1\right]$$

But $\frac{Z_o}{Z_i}$ is the closed-loop computing gain for a perfect amplifier, K_c. If there is more than one input, K_c is the gain with all input impedances in parallel.

$$\Delta E_o = e_g (K_c + 1). \qquad (1)$$

In a typical example, say e_g = 10 mv, K_c = 10, and E_{out} = ± 100 v max., the error at the amplifier output would be 10 x 11 = 110 mv or 0.11% of full scale.

If we prefer to use the open-loop gain $K_a = \frac{E_{out}}{e_g}$, (1) becomes

$$\frac{\Delta E_o}{E_{out}} = \frac{K_c + 1}{K_a} \qquad (2)$$

For K_c = 10, and 0.11% error, K_a = 10,000 or 80 db.

A circuit for observing grid error voltage is shown in Fig. 2. The applied frequency should be low enough so that no separation is observed between forward and backward sweeps, and the amplitude should be adequate to swing the amplifier through its full output range. The oscilloscope should be very sensitive. Few oscilloscopes are stable enough on DC for simultaneous observation of drift voltages.

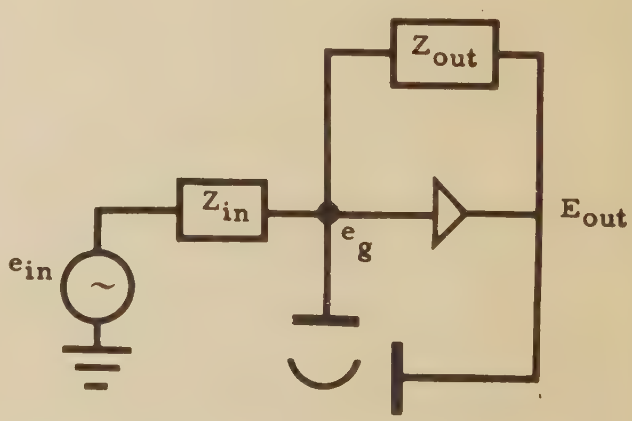


Fig. 2

Operational amplifiers used as amplifiers, as distinguished from integrators, will also have some dynamic error. The transfer function of a well-designed amplifier in its computing range can be accurately represented by

$$\frac{E_{out}}{E_{in}}(s) = \frac{K_c}{1 + T_s} \tag{3}$$

One method of evaluating the amplifier is to compare T with problem time constants. It should be negligibly small. If several amplifiers are used in cascade; their time constants may be added. Perhaps a more convenient interpretation is to compare the amplifier phase shift with the true system at some frequency of interest .A fast servo system will have 180° phase shift at, say 20 cps; a typical operational amplifier will have less than 0.1° lag at that frequency. The effect of amplifier phase shift is equivalent to measuring consistently true system phase shift high by the same amount. Thus the amplifiers need not be a great deal better than one's knowledge of actual phase shifts. Amplifier lags add cumulatively, not RMS, and can sometimes be troublesome in long computing chains. On the other hand, they can also be absorbed in computing lags in some cases. A good figure of merit for operational amplifier lag is the frequency f_h for which phase shift is 0.01 radian or about 1/2°. Normally problems should be scaled so that significant frequencies do not exceed f_h. From (3)

$$f_h = \frac{0.01}{2\pi T} \tag{4}$$

The principal component of T is the lag $R_f C_f$ due to capacitance C_f from output to input in parallel with the feedback resistance. Typical values of C_f are 4 to 50 $\mu\mu f$

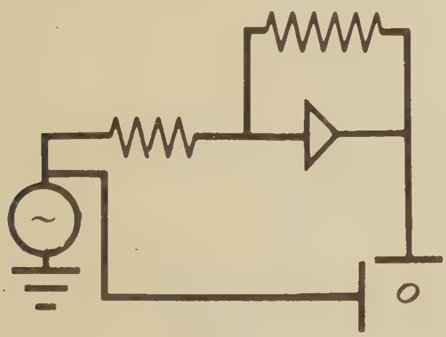


Fig. 3

and of R_f, 0.1 to 10 megohms. In addition, there will be a small component due to lag in the amplifier forward loop, which is dependent on closed-loop gain K_c. Thus

$$T = a(K_c + 1) + R_f C_f \tag{5}$$

C_f and a can be determined experimentally by operating the amplifier with very high and very low values of R_f, and measuring T. One way of measuring T is shown in Fig. 3. Phase shift is measured from a Lissajous pattern, using an oscilloscope with calibrated attenuator to expand the pattern. Then for phase shift ϕ radians at angular frequency ω radians/sec

$$T = \frac{\phi}{\omega} \tag{6}$$

A more elegant method, which requires no equipment outside the computer, is shown schematically in Fig. 4.

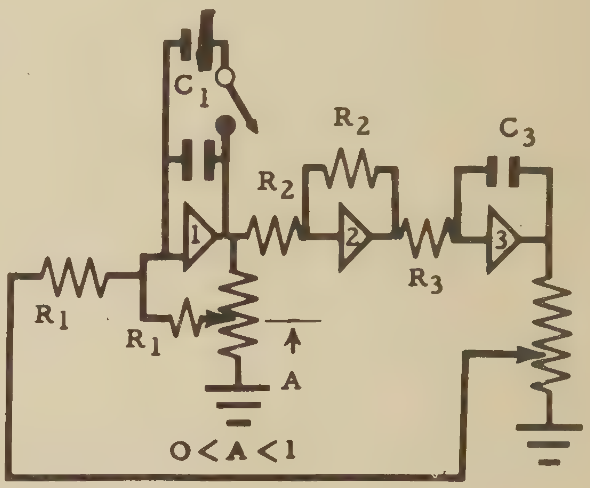


Fig. 4

When the switch is opened and $A = O$, the circuit oscillates at its natural frequency ω, preferably above 50 rad/sec. The oscillations will grow exponentially due to phase shift in amplifier 2. Control A is advanced until the oscillations remain exactly constant in amplitude. Then, as is shown in the appendix,

$$T = \frac{A}{W^2 R_1 C_1} \tag{7}$$

Lags in amplifiers 1 and 3 will not show up.

INTEGRATORS

An integrator is made by connecting a capacitor from output to input of an operational amplifier, and resistors from the input to signal sources. If there is a voltage e_g from input grid to ground, there will be a corresponding output voltage

$$e_o = \frac{1}{RC}\int_0^t e_g\,dt + e_g + e_o(O) \tag{8}$$

where C is the capacitance from output to input, and R is the resistance from input to ground, and e_o is the error in output voltage due to e_g. Since the computing time may be hundreds of times greater than RC, a minute constant input voltage can cause a substantial output voltage by the end of the problem, if not corrected. The majority of integrators in computers are used in closed loops so that error voltages are fed back around the loops, and gradually approach a limiting value. If an integrator's output is multiplied by a factor B, and returned to an input resistor R_2, where all the other input resistors in parallel have a resistance R_1, the steady-state integrator output due to grid voltage is

$$\Delta e_o = \frac{e_g}{B} \quad \frac{R_2}{R_1} + 1 \tag{9}$$

However, some integrators must be used without any such feedback, as in integrating airplane vertical velocity to obtain altitude. These integrators are one limiting factor in contemporary computers. If the grid voltage is a constant e_g, then the output error due to grid voltage

$$\Delta e_o = e_g \frac{t}{RC}.$$

If a certain accuracy must be maintained, the maximum computing time is limited by grid voltage, or if a computation must run for a given time, then the accuracy is limited by grid voltage. Occasionally it is necessary to use very large values of RC to get adequate performance, but most users find 1 second adequate. If an amplifier has ± 100 v maximum output, RC = 1 sec, and $e_g = \pm 0.5$ mv, then it may run for 200 seconds before it accumulates an error of ± 0.1% of maximum output. Two-hundred seconds is a fairly long time to run compared to the time constants of most systems which lend themselves to real-time simulation, and is fairly long if many runs are to be done in a day, while ± 0.1% is a respectable accuracy.

As in the case of the regular amplifier, grid voltage may come from finite amplifier gain, non-linearity or changes in the effective bias of the amplifier. It may also come from current flowing through the feedback capacitor leakage resistance. All of the effects except bias change may be eliminated by measuring deviations about zero output voltage. This is particularly convenient, since ordinary DC voltmeters are most sensitive around zero. The grid voltage due to the other causes is reasonably constant and is the same as that measured in the amplifier grid-voltage test above. The bias change, or drift voltage, is more random, and thus its integral is not readily calculated from the amplifier grid-voltage test.

One method of measuring drift is to connect an amplifier as an integrator, ground the input resistor and measure the output voltage as a function of time. Then we use the formula

$$e_g = \Delta e_o \frac{RC}{T}$$

to define a constant e_g equivalent in effect to the actual grid voltage.

A number of runs should be taken to get a fair picture. The average of absolute values and the median of the absolute values seem to agree closely after twenty runs, and the resulting value seems to remain fairly consistent for many individual amplifiers of the same design and manufacture. Typical values of e_g obtained in this way run about 0.1 mv for chopper stabilized amplifiers and 0.6 mv for conventional instrument-type amplifiers. The values of e_g obtained in this way do not seem to vary appreciably with the duration of the test run, over the range encountered in computing practice. The accuracy with which one can set the zero adjustment may affect the results substantially for such low voltages.

Long-term drift, over a period of hours or even days, need not affect the accuracy of computation, since the relatively few open-loop integrators in a problem can be reset just before critical runs. It can be annoying, however, and the long-term drift is of interest for this reason. It can be measured periodically in an amplifier connection, preferably with high K_c. Over the short computing time it may be treated as a constant. Typical values average 3-5 mv/hr. for non-stabilized amplifiers.

Grid voltages due to finite gain, non-linearity and capacitor leakage will generally exceed the short-term drift, and be comparable to the long-term drift. If it is desired to measure them for an integrator, rather than to use amplifier data for the first two, a simple test is still possible. The capacitor should be charged to some reasonable voltage with a battery, the input grounded, and the output voltage compared with the battery voltage as in the drift test.

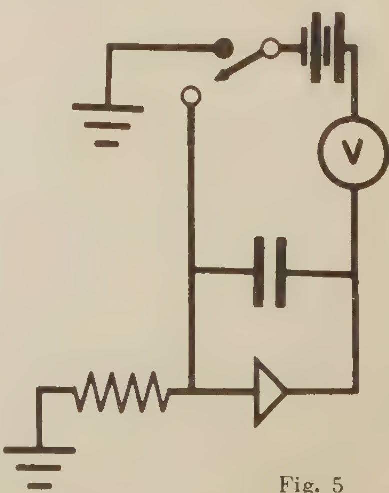


Fig. 5

Grid current flowing through the computing impedances also develops components of grid voltage. One component varies randomly like bias change, and another component is a function of amplifier output. For evaluation there is no point in separating the grid current components from the others. In amplifier development it may be desirable to separate them, by varying the impedance from grid to ground while keeping other factors constant.

Regardless of the cause the effect of integrator grid voltage is to limit the computing time for a given accuracy. A fair basis for evaluation is the time required to drift p % of maximum output with RC = 1 sec. Let us define it as

$$T_L = \frac{pE_{max.}}{100\, e_g} \tag{10}$$

The limiting value of e_g from the above tests should be used.

OTHER COMPUTING ELEMENTS

Other elements, such as multipliers and function generators, can be evaluated by obvious extensions of the methods used for amplifiers and integrators.

SYSTEM EVALUATION

In combining components to form a computer, and in applying the computer to solve problems, some interpretation and combination of the component data is required. It goes without saying that the component accuracies should individually be consistent with the accuracy required of them in combination. There is no point in paying the premium for 0.01% resistors with amplifiers that can introduce 0.5% error, and so on. A second type of consistency is required in the time domain, which bears discussion. In real time simulation, the components of the computer must not introduce dynamic effect not indicated on the block diagram, over the range of frequencies where the real system has significant response. For example, let us suppose that an aircraft has negligible response above 5 cps, and is thought to respond perfectly to commands which do not contain frequency components above 0.1 cps. Computer components should all have negligible lag below 5 cps, and negligible drift well beyond 6 seconds. The performance will be limited by computer servos at the high frequency end, and, let us say, integrator drift at the low end. If the aircraft is found to respond to signals up to 15 cps, then those servos just have to be made perfect up to 15 cps. If phugoid oscillations become important, the integrators must be improved so that their drift is negligible out to several minutes. This is a simple matter to analyze.

The situation is a little different when the computer is used alone to simulate a complete and independent system. First, the frequency range required increases, since different parts of the system have different significant frequency ranges, and the computer now represents all of the parts instead of just a few. Thus, in the example above an autopilot might have significant response out to 30 cps, and certain components within autopilot actuator loops might go higher yet. As if to compensate for this difficulty, the time scale may now be varied at will to take full advantage of the equipment's capabilities; sins committed at the high frequency end of the spectrum may be redeemed by virtues at the low, and vice versa.

One device for studying this situation is a dimensionless parameter which the author calls the dynamic resolution, R. R is the number of cycles of the highest arbitrarily permissible frequency contained in the longest arbitrarily permissible computing time. It may be applied both to problems, and to computing components and systems. The longest computing time T_L may be conveniently defined as the time for p % of error to occur; usually 1%. The highest frequency should be that for which $q/100$ radians of phase shift is introduced; usually 0.01 radian. Thus for the original airplane in the above example, R = 5 cps x 10 sec = 50 cycles.

$$R = T_L f^h$$

A computer which uses servomechanisms for multiplication, function generation and recording is obviously at a disadvantage in analyzing high-performance servomechanisms in real time. It is desirable for such a computer to slow time up by a factor of ten or more. The burden is then thrown on the low end of the spectrum; such computers must use elaborate means to control the drift which occurs over the long computing times they use. In a typical case, the highest frequency for acceptable accuracy would be about 1 cps, and the longest time about 20 minutes, so R = 1 x 1200 = 1200 cycles. Such a computer is theoretically capable of high accuracy in its servo functions, since the accuracy is determined by precision potentiometers. However, the mechanical parts and chopper stabilization are inherently expensive, and operating convenience and economy are poor because of the long solution times. Where values of R less than 1200 are required the solution time is reduced, so that part is not as bad as one might think at first.

If one replaces the servo multipliers and function generators with fast electronic ones the rest of the system has to change too. If the new computer is usable with equal phase lag to 30 cps, then to maintain a R = 1200, the maximum computing time required is only 40 seconds. Ordinary instrument type amplifiers may be used for much longer than that with good accuracy, even in open-loop integration. Fast recorders must be used, such as the Sanborn or Brush pen recorders, to record the

higher frequency components accurately. In this type of computer, when problems have a lower R than the computer does, they are generally scaled to be in the low end of the computer spectrum. This type lends itself much more readily to real time simulation, of course, being essentially ideal over the range of frequencies significant in mechanical apparatus. It is not as accurate inherently as the servo type, due to the static errors in contemporary electronic multipliers and function generators, and in pen recorders. Maximum errors in these devices run from ± 0.5% to ± 2% of full scale. However, the cost can be radically less, and the convenience probably better overall, because of the short solution times. If used as intended, even open-loop integrators will not require frequent rezeroing. If amplifiers designed for this type of computer are used with servo-type computers on problems involving very long solution times, they obviously should not be used as integrators, especially open-loop ones.

No discussion of system analysis can be complete without mention of the "AC" or repetitive computer. In an AC computer, actual computation time is reduced to a few milliseconds to eliminate integrator drift. Readout is on an oscilloscope, to be consistent with the computer frequency range. This makes output easier to observe, but more difficult to record. One high frequency limitation is in the operational amplifier itself, which is generally not true for the other types. In one version, the computing period is 4 milliseconds. For a gain of 1, and ϕ = 0.01 radians, f_h = 1000 cps. R = .004 x 1000 = 4. This very small value of R has seriously compromised the value of the equipment. If it had been run with a computing time of, say, 0.1 sec., the drift would still be negligible, and R = 100, a more practical value, although still pretty tight.

Another objection to ac computers is that they cannot be used in real-time simulation.

APPENDIX

Open-loop transfer function:

$$\underset{\text{amp 1}}{\left(\frac{1}{C_1 p + \frac{A}{R_1}}\right)} \underset{\text{amp 2}}{\left(\frac{K_2}{Tp+1}\right)} \underset{\text{amp 3}}{\frac{k}{R_3 C_3 p}}$$

$$= \frac{R_1 K_2 k}{A\left[\left(\frac{R_1 C_1}{A} p + 1\right)\left(Tp+1\right) R_3 C_3 p\right]}$$

Then the closed-loop transfer function is

$$\frac{\dfrac{R_1 K_2 k}{A\left[\left(\frac{R_1 C_1}{A} p + 1\right)\left(Tp+1\right) R_3 C_3 p\right]}}{1 + \dfrac{R_1 K_2 k}{A\left[\left(\frac{R_1 C_1}{A} p + 1\right)\left(Tp+1\right) R_3 C_3 p\right]}}$$

$$= \frac{\dfrac{R_1 K_2 k}{A}}{\dfrac{T R_1 C_1 R_3 C_3}{A} p^3 + \left[\dfrac{R_1 C_1 R_3 C_3}{A} + T R_3 C_3\right] p^2 + R_3 C_3 p + \dfrac{R_1 K_2 k}{A}}$$

Note that $$T \ll \frac{R_1 C_1}{A}$$

If A is adjusted for constant amplitude of oscillation, the transfer function must be

$$\frac{1}{\dfrac{p^2}{\omega_{n^2}} + 1}$$

where ω_n is the frequency of oscillation in radians/sec, in which case

$$\frac{T}{\omega_{n^2}} p^3 = \frac{A}{\omega_{n^2} R_1 C_1} p.$$

Under these conditions, $p^2 = \omega_{n^2}$,

so $$T = \frac{A}{\omega_{n^2} R_1 C_1}$$

THE MODEL II UNITYPER

Louis D. Wilson and Saul Meyer
Remington Rand, Inc.
Eckert-Mauchly Division
Philadelphia, Pennsylvania

SUMMARY – This paper relates some of the considerations at led the designers to develop the all-mechanical Model II nityper, in order to achieve a smaller, less expensive input anscriber than the larger electronic first model. Operational haracteristics are discussed, and the relationship of the unit the rest of the computing system is given.

After the Univac design was finished, its builders et out to develop an input transcriber capable of con-erting raw input material to magnetic tape recording. This transcribing function does not present a difficult esign problem in itself. However, the problems of oper-tor error with the consequent necessity for backspacing nd erasure, the necessities of monitoring operations and roducing visual evidence of the material recorded, and he task of converting large amounts of data in repetitive atterns, all tend to make the design quite complex. At he time the design was undertaken, there were no data vailable on the requirements which might be imposed on uch an input transcriber. There was only one sure indi-cation of what form the final system must take: it must be a tape recording device, for magnetic recording had been decided upon as the only feasible input-output medium. The transcriber incorporated every possible automatic operation and control function (instead of only a limited and arbitrary selection of those which appeared to be reasonable). It was fundamentally electronic in design, and was called a Unityper. Upon being constructed, the Unityper proved the practicability of transcribing raw data directly from a keyboard onto a magnetic tape.

To accommodate both alphabetic and numerical data, this Model I Unityper uses for a layout pattern the key-board of a typewriter. The operation of the device is cyclic in character. The striking of a key on the keyboard discharges a capacitor into a resistor matrix which sends a code combination to the channels of the mag-netic recording head. The pulse from the keyboard sets a delay-flop whose output triggers a 96-pole motor from one stable state to the next. This motor operates the centerdrive, moving the tape 1/20th of an inch. When the tape has traveled and stopped, the equipment is ready to receive a new code combination.

In addition to this relatively straightforward cycle of operation, the initial design incorporated an automatic operator, which enables the typist to keep one code com-bination recirculating through the system for a controlled length of time. This permits the automatic execution of repetitive operations such as filling, and the automatic recording of code patterns which recur continually. A number of alarm circuits prohibit such mistakes as striking two keys at the same time, violating one of the many possible control "fields" of the automatic operator, backspacing into the space between blocks, typing too many words in any block, and other error-operations. Furthermore, each reel is separately powered by means of a 1/4-horsepower torque motor, and the 96-pole syn-chronous stepping motor already mentioned operates the centerdrive system. The reel motors require brakes and brake controls to ensure that the tape is kept taut in its path at all times, and yet not subjected to over-tensing.

With the limited production facilities at the disposal of the Eckert-Mauchly organization at that time, it was natural to evolve an electronic design which could be constructed with the same assembly procedures used for the Univac itself. The Model I Unityper has been put into extensive use transcribing all types of data. Out of the experience with functioning data-processing systems has come an evaluation of the various features which was not available when the first Unityper was in the blueprint stage.

One critical factor, among others, is that an elec-tronic device operates at speeds beyond the necessities of the human operator. The operating speed of mechanical equipment is adequate to these necessities, and the equipment itself is less expensive. The larger mechanical facilities and skills of the Remington Rand organization permitted the mass production of die-stamped and ma-chined assemblies. It was therefore decided to explore the possibilities of a mechanical transcribing device that would use as much as possible of predesigned and stand-ard mechanical equipment. The resulting Model II Uni-type, shown in Fig. 1, is much smaller and much less costly to build, and at the same time retains all the features of Unityper I that have proven worthwhile in a keyboard-to-tape transcriber.

REQUIREMENTS

Since the typewriter keyboard presents a familiar and simple layout of the numerical and alphabetical elements of data, it was decided to investigate the feasi-bility of using a standard electromechanical typewriter. A little investigation disclosed some interesting parallels between the operations required of an input transcriber and the operational characteristics of a typewriter.

First there is the coding problem. For each key depressed on the transcription device, a combination of eight possible pulses must be coded up and sent to the eight channels of the recording head. Each key must produce a unique combination of these pulses.

On most electromechanical typewriters, the movement of a key brings an associated eccentric into contact with a constant-speed power roller. The eccentric, in turning, pulls down the typebar mechanism, which flips the typebar toward the platen. Each key is associated with only one eccentric and only one typebar.

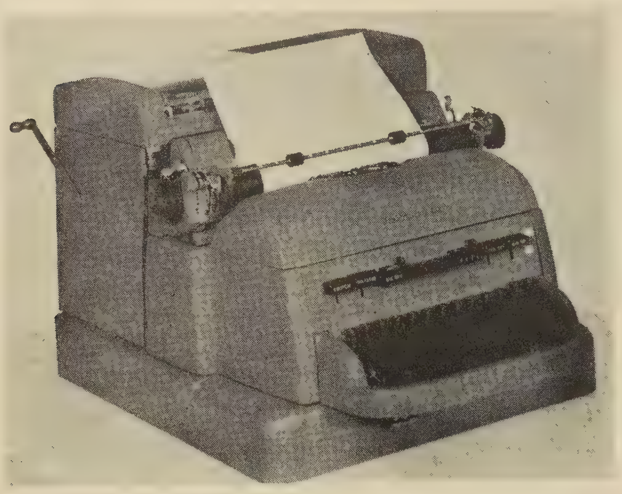


Fig. 1 – The Model II Unityper.

A mechanical system of eight bails, one for each pulse of the eight-channel code, operated by lift-arms connected to the typebar mechanism, can serve as an encoder if each bail is selectively notched according to the pulse code, and connected to a switch for passing the recording currents. This provides a magnetically reproducible code pattern, while the normal mechanism of the typewriter provides a printed record of the material typed in.

The next requirement imposed on the system is that of obtaining discrete tape movement. Because the tape must occasionally be stepped backward one space at a time, for entering corrections, etc., the tape drive must move the tape the same distance in both forward and backward operation. But this requirement is also imposed on typewriter mechanisms: the carriage escapes a discrete distance for each character typed, while backspace moves the carriage exactly the same amount in the opposite direction. The distance is mechanically fixed by the escapement mechanism. The decision here was again obvious: use the motion of the one device to generate the same order of motion in the other.

THE TYPEWRITER

The basic unit of the Unityper is a Remington Rand Electri-conomy typewriter. Its purpose in the scheme of things is to provide a familiar starting point for the encoding process, translate the single letters or digits into the multi-element code, and produce a printed copy of the material encoded. Many of the functions of the typewriter are tapped to provide for other functions required throughout the Unityper.

The standard machine has 42 keys, which connec through mechanical linkage to 42 eccentrics, each o which can activate a typebar. The action of each typebar allows the carriage to escape one letter-space; on a machine using elite type, which is the type size used on the Unityper, the carriage escapes 1/12".

Power Linkage The linkage from one key through a power arm to its eccentric and the typebar is shown in Fig. 2. The ball interlock, and the lift-arm extending down from the center, do not exist in the original typewriter mechanism. The rest of the linkage is all standard on the Electri-conomy typewriter. The heavy straight arrows on the drawing indicate direction of movement of the various members, while the curved arrows are drawn around the various pivot points.

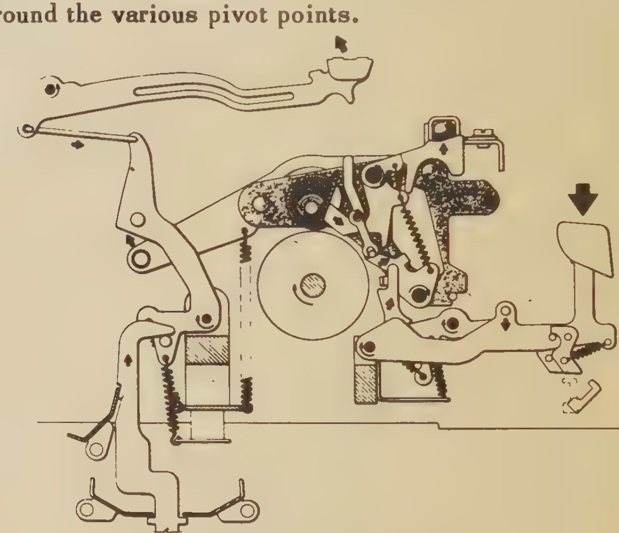


Fig. 2 – Power Arm and Linkage.

A pressure on the key works through the intermediate linkage to perform three functions: to bring an arm to bear on the nylon eccentric; to disengage the lock member from the undercut in the eccentric, and to push a blade (which pivots the lock member) into the ball interlock slot shown in the upper right portion of the drawing.

The eccentric is pushed down onto the power roller which rotates constantly. The power roller drives the eccentric through one complete rotation. As it turns, the eccentric raises the entire power arm assembly, which pivots at one end. Mounted on the other end of the power arm is a small roller which rides against the flat surface of the actuator bell crank. When the actuator bell cran pivots, it draws the typebar pullwire to the right. Due to the arm ratio of the typebar, the short pull on the wir flips the typebar sharply toward the platen.

The intermediate linkage from the key is disengaged after one operation. The lock member rides against th eccentric until the undercut appears, then falls back int the locked position. The shape of the eccentric allows i to clear the power roller just before it is re-engaged b the lock member.

The interlock trough of forty-nine balls contain just enough space to accommodate one lock blade.

cond key cannot be operated until the first eccentric urns to its normal position, due to the fact that two ades cannot enter the trough at the same time.

The actuator bell crank has been modified for Unioer II by the addition of a pin at its lower end, which gages the hooked portion of the encoder lift-arm. When e lift-arm is raised, it engages a combination of the coder bails to set up the code.

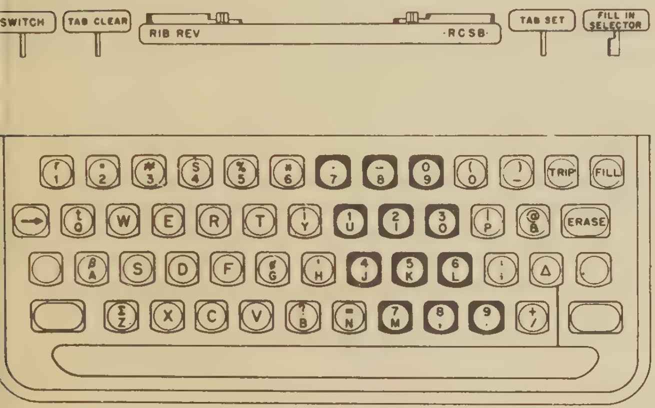


Fig. 3 - The Keyboard.

Keyboard and Modifications The keyboard is illusated in Fig. 3. The modifications and changes from the andard keyboard include the following:

...Two keys have been added on the top bank: the numeral 1 to the left of the 2, and TRIP key at the right end.

...A keyboard of numerals has been included in the upper-case positions of part of the right hand side of the keyboard. These were added to provide a convenient keyboard for typing all-numerical data. The upper-case positions of some other letter-keys have been used for symbols of special significance to Univac.

...A failsafe solenoid-operated keyboard lock, sometimes called the line lock, has been added to prevent operation of the keyboard at all times except during the Type stage of the operating cycle.

...The standard CARRIAGE RETURN key has been replaced by a key marked ERASE. The function insofar as typewriter operation is concerned is identical, however.

...The normal TAB key is marked FILL; the function is almost the same, excepting that the FILL operation records either space symbols or zeroes on the tape according to the position of a FILL SELECTOR switch. This switch, in the position of the normal MARGIN RELEASE, enables the operator to select either space symbols or zeroes when filling in unused block space by tabbing through it. (The margin is fixed at 120 characters; there is consequently no need of a margin release on the Unityper.)

...The SPACEBAR is disconnected from the normal carriage escapement, and mechanically coupled instead to the key marked Δ in the drawing. Operation of the spacebar thus not only records the symbol meaning space on the tape, but prints a Δ on the paper. In this way the user is assured that there is a symbol on the paper for every symbol on the tape. For example, an operator cannot backspace too far and then merely space to the correct position (which normally would erase all previous data from the tape and enter the space symbol instead); she must, if she backspaces too far, re-enter all the information in its correct position. If she does not, the Δ symbol shows up on the paper overriding the previously entered data.

...All margin controls and manual carriage controls are removed, so that the number of characters in a line is fixed (at 120), and so that the carriage cannot be moved to the left except by depressing a key or the spacebar. To prevent its manual movement to the right, an additional escapement wheel has been added, which is indexed in the opposite direction from the normal escapement. This makes it necessary to use either BACKSPACE, ERASE, or TRIP key when moving the carriage to the right. It is thus impossible to move the carriage in either direction except from the keyboard.

There are four other modifications to the typewriter to accommodate the requirements for Unityper II. The mechanical ball interlock in the linkage from the keys, which prevents the striking of two keys at the same time, has already been mentioned. The lift-arms and encoding bails, mounted unter the typewriter, will be treated in detail a little later. The two additional components are a commutator with two faces, which is turned by the carriage escapement; and a power takeoff from the typewriter motor.

The power takeoff is led through a flexible cable into the tape panel behind the typewriter, where it is terminated in a rubber capstan inside an annular channel concentric with the hub of the center drive wheel. This capstan can be moved against either the inner or outer ring of the annulus, for the purpose of providing fast forward motion to load a length of leader tape at the start of a reel, or fast reverse motion for rewind. Normally, however, it spins disengaged from either ring, and the movement of the carriage operates the center drive.

These modifications permitted a design for an encoder and for a tape transport system which are driven and controlled by the typewriter action. The removal of the margin and carriage controls and the addition of the ball interlock also provide accuracy and safety guarantees.

The Encoder The encoder is the name given to the portion of the Unityper which translates the movement of a typebar into a pattern of magnetic pulses across the width of the Univac tape. Its primary purpose is one of translation: the single character identified by the key and the typebar must be translated into a unique combination of eight characters representing the digit or letter to the computer. The encoder is housed underneath the typewriter, and is completely mechanical.

The striking of a key on the typewriter acts through its eccentric, as described above, to flip the typebar and raise the lift-arm. The cutaway view of the encoder (Fig. 4) illustrates a few of the lift arms, and shows the notches which are cut into the horizontal encoding bails. All forty-four of the lift arms are the same; the eight bails are notched so that any one bail will be pulled up by the projection on the lift-arm only if the character associated with that lift-arm requires a pulse in the digit-position represented by the bail. Each of the bails operates a switch, which closes when the bail is engaged. In this way the switches set up the code for each character. They connect directly to the head through a resistive balancing circuit.

The lift-arms are held up in position by a latching bail, also illustrated in Fig. 4. The bail is so placed

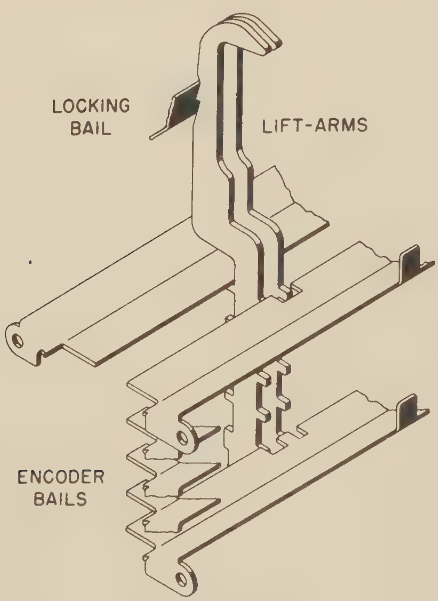


Fig. 4 – Detail of the Encoder.

that it catches against a sawtooth notch on the shaft of the lift-arm, and locks it into position after it is selected.

After the bar has pulled up a combination of bails, and the code is set up, one face of the commutator disc applies recording power through the switches to the head. The commutator is geared to the carriage escapement, and steps twenty degrees for every character.

In each twenty-degree sector of the circle are two contacts, on opposite faces of the disc. The two sets of contacts are displaced from each other by approximately ten degrees. The first of these applies the recording voltage to the head; the second connects the actuator power source to an unlatching solenoid. This solenoid, when it closes, removes the latching bail so that the lift-arm returns to its normal position after the recording takes place.

Between carriage movements, no recording power is applied through the switches. An erase voltage, however, is applied to the resistive balancing circuit at all times except during rewind, so that all channels of the recording head erase when they are not specifically set up for recording.

The shift operation is accounted for in the encoder by having the entire arrangement of bails shift to the left when the type basket is shifted. The notches cut in the bails differ in the two positions if the upper case character on the keyboard differs from the lower case. The code can be changed entirely by this means; there is no inherent necessity for an upper case character to bear any relation to the lower case character on the same key.

During BACKSPACE, all power is removed from the head by a switch, so that neither recording nor erasing occur while the carriage is being stepped backwards. The switch operated by the backspace actuator solenoid opens the ground return from the head. It was included to accommodate the overshoot of the carriage when it is being stepped backwards. The erroneous information on the tape is erased as the corrected version is entered.

THE TAPE PANEL

The remaining functions of the Unityper are merely those of a tape transport device which operates synchronously with the typewriter. The tape panel, which contains the components necessary to fulfill these functions, is mounted behind the typewriter. In a space the height and width of the typewriter and approximately eight inches deep are enclosed the takeup reel, the supply reel mount, the erasing and recording heads, and the apparatus which controls the operating cycle of the Unityper.

The tape panel is substantially a mechanical device. There are no motors or vacuum tubes in it, and what motive power is required is furnished manually (as in the case of pulling the operating lever), or applied from the typewriter. Of the switches in the tape panel, all but one are mechanically operated.

Centerdrive The centerdrive mechanism is powered by the typewriter itself. Mounted on a standoff which is

bolted to the carriage is a double clamp (illustrated in Fig. 5), which has two engaged positions and one neutral. Through each of the two clamp positions runs one loop of a belt which wraps around the centerdrive wheel under

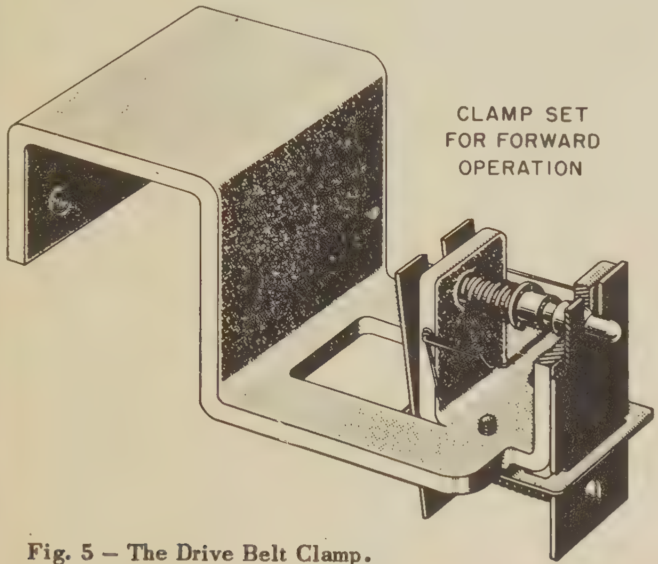


Fig. 5 – The Drive Belt Clamp.

the motorboard of the tape panel. For motion of the carriage in a given direction, one loop turns the centerdrive wheel in a direction opposite to the other. The threading of the drive belt is illustrated in Fig. 6.

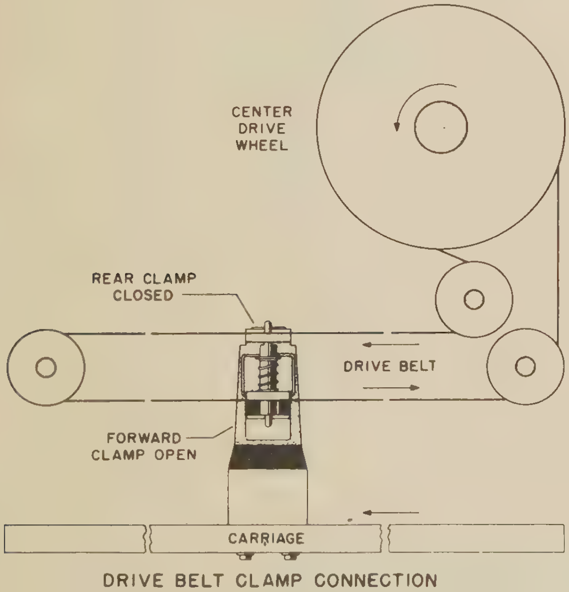


Fig. 6 – Drive Belt Clamp Connection.

The clamp is spring-loaded in such a fashion that it tends to grasp the forward of the two loops. It is normally set, however, so that it clutches the rearward of the two. In this state, motion of the carriage to the left (normal typing) moves the centerdrive counterclockwise, which feeds tape in a forward direction through the system and past the recording head. At the end of a correct line, the carriage must be returned to the right, but the tape must continue to feed forward. The TRIP key, added on the right end of the top bank of keys, operates the carriage return mechanism through an actuator; at the same time the TRIP key sends power to another solenoid which trips the drive clamp and jams it into its stable state, clutching the forward loop of the belt. This reverses the relation between the carriage and the tape drive so that tape continues to feed forward while the carriage is returning.

At the end of an incorrect line, or at any point where the operator desires to erase the whole line of type from the tape, the ERASE key may be depressed. This merely returns the carriage; since the tape drive clamp is not tripped, the tape feeds backward too, and so is erased. The same case holds true for BACKSPACE, excepting that the head circuit is opened, and the single character is not erased until the next recorded character overrides it.

In the neutral state, which can be entered into only while the carriage is in the first-digit position, a cam holds the drive clamp in the middle of its travel, so that neither the forward nor the rearward clamp is engaged, and the drive belt passes freely through. This position is used during rewind, and while the device is loading the necessary length of leader tape at the beginning of a reel. During these operations, the centerdrive wheel is rotated directly by means of the power take-off from the typewriter motor.

The ratio of the diameters of the centerdrive wheel underneath the motorboard, and the centerdrive capstan above the motor-board, is such that for each ten inches of travel of the carriage, which causes ten inches peripheral displacement of the centerdrive wheel, the centerdrive capstan transports two and four-tenths inches of tape past the recording head. Since the pitch of the type is twelve to the inch, the density of recording on tape is fifty characters to the inch.

The 10:2.4 ratio is further useful in providing for the space required to give the Uniservo time to stop and start between blocks. The input synchronizer in the computer can accept only 720 characters at a time; all information read into the computer by the Uniservo therefore must be in 720-digit blocks. Between these blocks must occur a sufficient space for the Uniservo to start and stop.

The carriage is fixed on the Unityper so that only 120 characters will be accepted as a line. Less than this amount will not permit the TRIP operation to take place; more than this amount cannot be accepted by the typewriter since the margin and keyboard are locked and will not release. As the carriage is returned after each line, the ten-inch travel of the carriage causes the tape to be moved 2.4". These spaces contain no information, and are normally passed over and ignored by the Uniservo. However, after the sixth line, the counter in the input circuits of the central computer has reached 720. A signal is sent to the Uniservo to indicate that the block is

completed and that the input register is full. The Uniservo then coasts to a halt in the sixth space, which assumes the significance of a space between blocks.

The writing head used on Unityper is the standard eight-channel electromagnetic head used throughout the Univac System. A special permanent-magnet erasing head is mounted in the tape path just in advance of the recording head, so that the tape is erased before it is passed through the recording fields. This head is automatically removed from its position against the tape during the Rewind process.

Reel Control The two reels are the same size. Any constant rotation of either reel causes a non-linear feed of tape, due to the fact that the very act of feeding tape from one reel to the other increases the effective diameter of one reel, and decreases that of the other.

In the design of Unityper I, both reels were powered separately, and the size of the free tape path was sensed to determine which of the two reels had to be unbraked to keep the proper amount of tape in the path. However, the design of the Model II Unityper aimed to simplify this process. The requisite motive power already exists in that the movement of the tape can move the reels if they are properly mounted. The problems are to accommodate the differences in the relative diameters of the reels, and to include a mechanical low-pass filter between the reels and the centerdrive such that the high-inertia reels need not respond to the large accelerations experienced by the centerdrive capstan.

The solution to the latter problem involved mounting two of the pulleys around which the tape passes in a very light floating frame, so that discrete elements of movement are absorbed. The intermittent motion of the centerdrive capstan is consequently smoothed out, and a slower response to a larger integrated motion is all that is expected of the reels. To solve the differential problem, both reels were mounted on the same axis, but not on the same axle. The supply reel mount is above the motor-board of the tape panel for easy accessibility; its shaft, which forms the axis of the entire reel assembly, projects down through the motorboard to terminate in a buttplate at the bottom of the assembly. The takeup reel, which is not removable, is below the motorboard. It is fixed, at a point about half-way from its center, to a differential spring of the clock mainspring variety. An exploded view of the reel assembly is given in Fig. 7.

The inner diameter of the clockspring is permanently attached to a drum which surrounds the supply reel shaft without touching it. Contact between the drum and the shaft is obtained through a spring clutch, fixed at its lower end to the shaft buttplate, and wound around the takeup reel drum.

An equilibrium is established between the differential spring tension and the tensions in the tape path. When the centerdrive wheel turns, and tape is pulled out from the supply reel, the resulting imbalance permits the differential spring, inside the takeup reel, to operate to turn the takeup reel. The centerdrive, in other words, supplies the force that pulls both reels. The differential spring merely absorbs the differential moment resulting from the difference in working diameters of the two

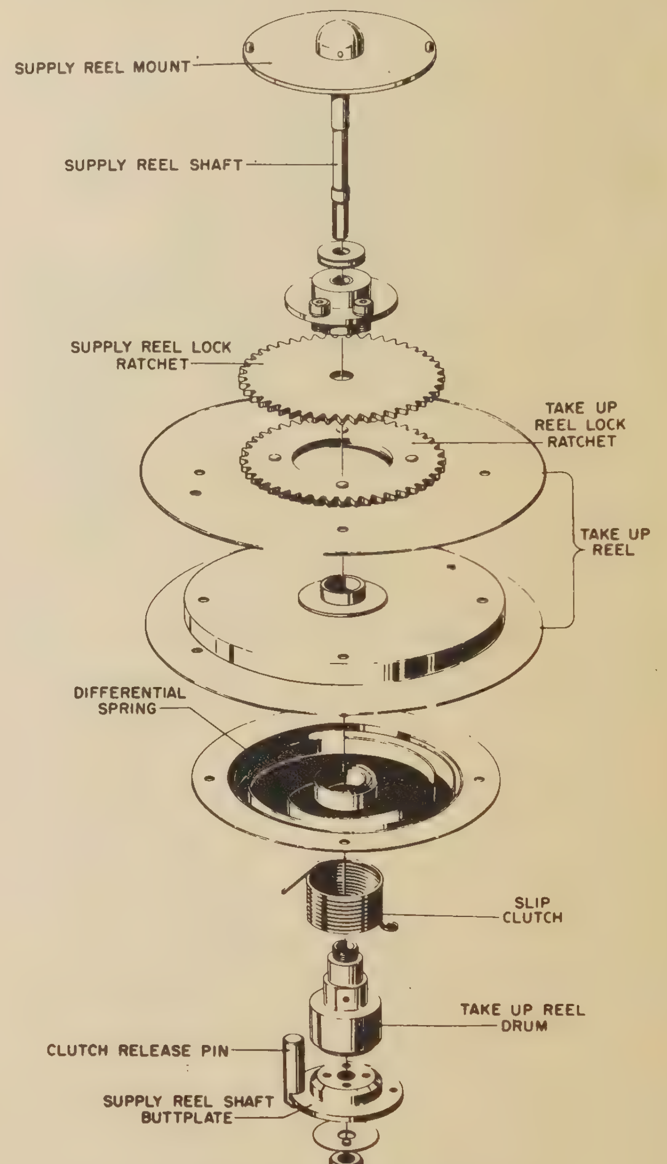


Fig. 7 – Exploded View, Reel Assembly.

reels. Since the force of the clockspring is proportional to its compression, and since it is fully wound to start with, the takeup reel is subject to a greater force when it is empty than at any other time. It consequently tends to accelerate more rapidly at the beginning of a tape run than subsequently. However, its applied tension decreases as it unwinds. When the supply reel is half empty, the takeup reel is half full; from this point until the supply reel is completely empty, the same linear travel of tape will tend to move the supply reel more than the takeup reel. The supply reel, of course, can move freely as the tape pulls it. The takeup reel can move no farther than the free tape will permit. Since it cannot turn

far as the supply reel turns, there is again a differential moment. This is absorbed by the clockspring, which becomes wound. When the supply reel has been completely emptied, the clockspring is rewound to its original compression.

The rotary motion of the supply reel shaft is transmitted through a helical coil clutch spring wound around the takeup reel drum. This coil is fixed at its lower end to the buttplate at the base of the shaft. Its upper end is brought out about half an inch on a tangent to the normal circumference. A detail of this clutch spring, the drum, the axle, and the differential clockspring, as they appear when assembled, is given in Fig. 8.

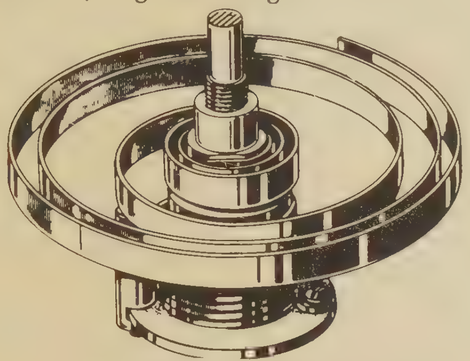


Fig. 8 – Differential Spring and Clutch.

The inner diameter of the clutch spring and the outer diameter of the takeup reel drum are the same when the clutch is not under stress. When the supply reel shaft turns, the clutch spring is turned too. It compresses around the drum and turns it, allowing the takeup reel to turn, and winding the clockspring.

When the potential force built up in the clockspring is equal to the force inherent in the coil, the coil wraps around the drum so tightly that the lower windings are forced into the undercut at the base of the drum. The tightening of the coil decreases the inner diameter, and permits the lower windings to turn with respect to the upper windings. The projecting end moves into contact with a pin fixed to the buttplate, also shown in Figs. 7 and 8. The pin opens the coil, allowing the drum and the shaft to turn free of each other. This prevents any accidental overwinding of the clockspring, which might break the spring.

Since the tape is in equilibrium between the force of the clockspring and the tensions of the free tape path, overwinding of the spring might also strain the tape and decrease its life. However, this safety feature is not required during normal operation, since the spring can only wind as much as it was unwound. The only time the clutch will open in this manner is when the clockspring is initially wound up. The initial winding is done by turning the supply reel mount by hand with no tape in the tape path. The supply reel will turn, winding the clockspring, until the clutch slips. After that any further turning of the reel will result in the clutch's slipping without either winding the spring or doing any harm to the system.

THE OPERATING CYCLE

The controls of the operating cycle of Unityper II, like the rest of the system, are mostly mechanical. An operating lever on the left side of the tape panel operates an arrangement of cams and bell cranks to institute a regular cycle of Load Tape, Load Leader, Type and Rewind. The Load Tape and Type positions are automatically entered into, following Rewind and Load Leader respectively. Operator's decisions control the points at which Rewind and Load Leader are brought about; the two operations can be initiated only under certain fixed conditions, however.

Part of this same operating control mechanism is for the purpose of providing certain safety interlocks. Other parts open or close the recording voltage circuit and the keyboard lock actuator circuit. One cam is for the purpose of holding the tape drive clamp in its neutral (unstable) state, so that both loops of the drive belt can pass freely through the clamp during Load Leader and Rewind. Another bell crank positions the power takeoff inside the annular channel of the centerdrive wheel, so that during these two stages of the cycle the wheel moves rapidly counterclockwise or clockwise without any carriage movement.

Other control components in the tape panel:

1. Provide automatic locks to lock the door from the time operation starts on any tape until that tape is rewound;
2. Latch the two reels in fixed position when the door is opened, and lift the latches off only when the operating lever is next pulled;
3. Lift off the pawl which normally couples the operating lever to the control ratchet whenever the machine is busy with some function, so that the mechanism is not permitted to try to do two things at a time;
4. Provide a method of stopping the rapid-action stages of the operating cycle, Load Leader and Rewind, without operator interference.

When the operator has loaded a blank reel of tape on the supply reel mount, she shuts the door and pulls the operating lever (the operating lever will not function unless the door is shut). The Unityper automatically loads fifteen feet of tape onto the takeup reel; in the meantime, a stop nut is fixed laterally so that it rides up a screw, stopping the load action when it reaches the top of its travel. The machine is then ready for typing. A cam-operated switch automatically activates a solenoid to release the keyboard lock at this time. The keyboard lock, or line lock, is released only during the Type stage of the operating cycle.

The operator proceeds to type. If she makes a single error, she operates the backspace to correct it; this not only returns the carriage one digit-space, but backs the tape up a corresponding amount. While the tape is back-

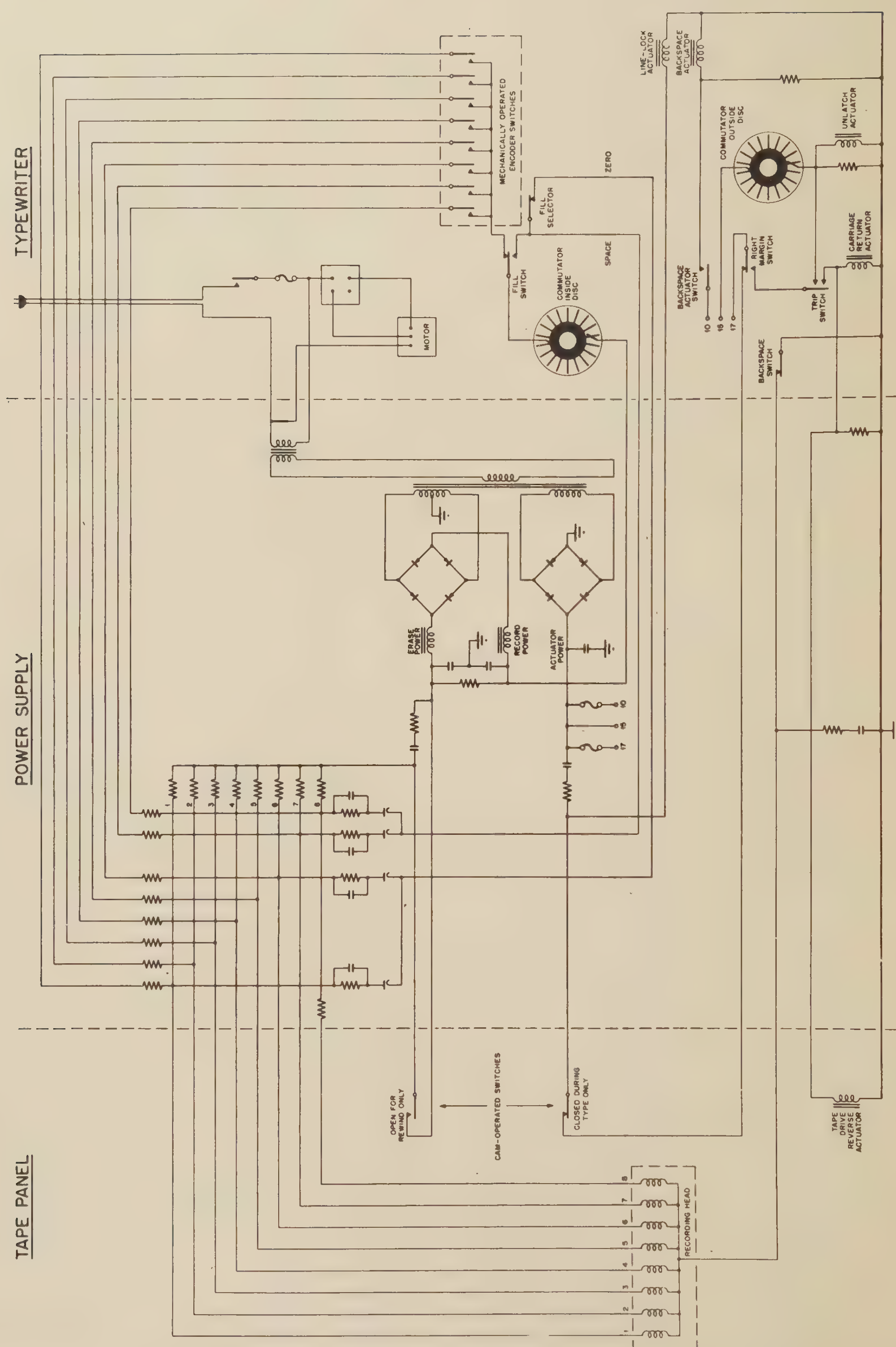


Fig. 9 – Schematic Diagram, Unityper II.

ing up, a switch opens the ground return circuit from the head coils, so that neither erasing nor recording can be done over the incorrect area. When she reenters the correct version, the incorrect digit or digits will naturally be erased.

If she makes more than one error, she may want to erase the whole line. The ERASE key is identical with the normal carriage return; the carriage is drawn back to its left limit, the tape travels with it, and the entire line of data is erased as it passes over the head.

If the TRIP key is struck at any time except when the carriage is at the right margin, it will print an underscore without moving either carriage or tape, and without recording anything on the tape. When the 120th digit has been entered in any line, however, and the carriage moves into the 121st digit-position, the right margin switch closes. Depressing the TRIP switch at this point will apply power to two actuators: one to operate the carriage return mechanism, and the other to reverse the tape drive so that tape will be fed forward while the carriage travels backward. The unlatch actuator also receives power, so that the encoder will be cleared to start the new line. The tape drive clamp is reset as the carriage approaches its left limit.

In each 1st-digit position, the handle pawl on the operating lever drops onto the control ratchet, so that the operator may initiate a rewind after typing any complete line. The operating lever is disabled by the raising of the pawl immediately after the first digit is entered, since rewind is never required excepting at the end of a line of information.

Rewind, when initiated by the operator, stops automatically as the last loop of tape unwraps from around the takeup reel. A spring leaf which is held by the tape against the hub of the takeup reel springs out and trips a pawl on the control mechanism, which indexes into a neutral position and stops the rewind.

THE POWER SUPPLY

The power supply for the Model II Unityper consists of two selenium bridge rectifiers, one of which is grounded at its center. This bridge produces equal positive and negative voltages, the former for erasing and the latter for recording. The second bridge provides actuator power for the various control solenoids in the machine.

The positive and negative voltages are applied to the head through a resistive balancing circuit, also located in the power unit. Because the recording voltage is applied through a commutator, the duty-cycle of the recording operation is mechanically determined. The erasing voltage, on the other hand, is applied at all times excepting during backspace and rewind. The two cam-operated switches which open the erasing voltage circuit during rewind and close the circuit to the keyboard lock release for typing are located in the tape panel, and are operated by cams on the control shaft of the operating lever.

The power consumption of the Model II Unityper is 75 watts, including the power consumed by the 1/28-hp motor of the typewriter itself.

The complete electrical schematic of the Unityper is given in Fig. 9. Although it covers only a small amount of space, this schematic describes a complete unit which adequately fulfills the input requirements of the Univac System.

ACKNOWLEDGEMENT

The authors wish to express their gratitude to E. Roggenstein of the Laboratory for Advanced Research, and others of the Remington Rand organization who contributed to the research and development of the transcriber discussed here, and to F. J. Leary for his editorial assistance in the preparation of this paper.

CONTRIBUTORS

LEE CAHN (S'48–A'49–M'50) was born in Washington, D.C., on July 12, 1926. He served in the U.S. Navy where he went through the Electronic Technician School. During the periods 1944-45 and 1946-48 he attended the Massachusetts Institute of Technology, receiving the S.B. and S.M. degrees in Electrical Engineering. From 1948 to 1950 he was head of the Development Department, Special Devices Division, Askania Regulator Company, working on automatic submarine controls and simulators. From 1951 to 1952 he was employed in the Electromechanical Department of North American Aviation, Inc., as supervisor of the Test Equipment Unit, responsible for special laboratory instrumentation of missile guidance systems. Since 1952 he has been with Beckman Instruments, Inc., where he was in charge of EASE Computer program, and is now Spectrophotometer Group Leader.

CARL E. HOWE (M'45) was born in Maitland, Pennsylvania, on May 16, 1898. He received the A.B. degree in 1919 from Juniata College, and the Ph.D. in physics in 1929 from the University of Chicago. From

1920-22 he was instructor of science at Blue Ridge College. The next two years, 1922-24, were spent as instructor of biology and physics at Juniata College. From 1922 to 1924 he was assistant professor of physics at Oberlin College. While completing his graduate work in physics, 1926-29, he was a teaching assistant at the University of Chicago and an instructor at the Central Y.M.C.A. College. Since 1929 Dr. Howe has been a member of the physics staff at Oberlin College where he is now Professor of Physics.

Dr. Howe's teaching and research has been chiefly in the fields of x-rays and electrical theory and measurements with particular emphasis on applied electronics. The research includes precision measurements of x-ray wave-lengths, x-ray studies of strains in piezoelectrically oscillating quartz, design and application of electronic differential analyzers, experimental studies of vibrating beams, precision frequency measurements, design of electronic equipment, etc. Some of this research has been done during summers at the Naval Research Laboratory (1931), Princeton University (1945), and the University of Michigan (1947-53).

Dr. Howe is a member of Sigma Xi, the American Association of Physics Teachers, the American Association for the Advancement of Science, the Ohio Section of the American Physical Society, and the Institute of Radio Engineers.

ROBERT M. HOWE was born in Oberlin, Ohio, on August 28, 1925. He received the B.S. degree in electrical engineering in 1945 from the California Institute of Technology, the A.B. in physics in 1947 from Oberlin College, the M.S. in physics in 1948 from the University of Michigan, and the Ph.D. in physics in 1950 from the Massachusetts Institute of Technology. From 1947-48 he was a research associate at the Engineering Research Institute, University of Michigan, where he did basic research on the design and application of electronic analog computers. From 1949-50 he carried on fundamental research in low-pressure mercury arcs as a research assistant at the Research Laboratory of Electronics, M.I.T.

In 1950 Dr. Howe returned to the University of Michigan in the Department of Aeronautical Engineering, where he is currently an assistant professor in automatic control, guidance of pilotless aircraft and missiles, and nuclear engineering. In addition, he is continuing research on electronic differential analyzers, flight simulators, and weapons systems.

Dr. Howe is a member of Phi Beta Kappa, Tau Beta Pi, Sigma Xi, the American Institute of Physics and the American Association for the Advancement of Science.

RUDOLPH J. KLEIN was born in Joliet, Illinois on June 12, 1929. He received his B.S. degree in electrical engineering in June, 1950 from the Georgia Institute of Technology.

In September, 1950 he joined the Instrument Department of the Oak Ridge National Laboratory. In January, 1951 he was loaned to the Argonne National Laboratory to assist in the design and construction of a large digital computer, the ORACLE. In October, 1953, he accompanied this computer back to the Oak Ridge Laboratory where he is assisting with the installation of the computer and the design of auxiliary equipment.

Mr. Klein is a member of the Association for Computing Machinery, Tau Beta Pi, Eta Kappa Nu, Phi Kappa Phi and Phi Eta Sigma.

SAUL MEYER (M'53) was born in Philadelphia, Pennsylvania in 1926. He received the B.S. degree in Electrical Engineering from Drexel Institute of Technology in 1950.

He served in the United States Navy from 1944 to 1946 as a Radio Technician. Since 1950, he has been with the Eckert-Mauchly Division of Remington Rand Inc., doing design and development engineering on Input-Output equipment for digital computers.

Mr. Meyer is a member of Eta Kappa Nu and of I.R.E.

LOUIS D. WILSON (M'46) was born in Philadelphia, Pennsylvania on December 17, 1917. In 1941 he received the B.A. degree and in 1942 the M.A., both in physics from Temple University.

From 1942 to 1944 Mr. Wilson was a teaching fellow in physics at the Massachusetts Institute of Technology, and from 1944 to 1945 an instructor in electrical engineering.

He then became a research engineer at the Servomechanisms Laboratory, remaining until 1947. During this period he was concerned with the electrical design of the Whirl-wind computer, and was in charge of the development of arithmetic curcuits.

Since 1947 Mr. Wilson has been with the Eckert-Mauchly Division of Remington Rand Inc., working on the logical design of the BINAC computer, the circuit design for the BINAC and UNIVAC computers, and also on the development of special input-output devices for use with the UNIVAC System. In 1951 he was named project engineer responsible for development of input-output devices.

REVIEW SECTION

It is the intention of this section to review articles that have been published since January 1, 1953, and to publish eventually reviews of all books pertaining to the computer field. All articles and books reviewed are numbered sequentially for each year; where known, the Universal Decimal Classification number is also given. The editors wish to express their gratitude to the reviewers who, through their efforts, make this section possible.

H. D. Huskey, Editor

GENERAL

53-51

An Evaluation of Analog and Digital Computers (Panel Discussion)—G. D. McCann, J. L. Barnes, L. N. Ridenour, Floyd Steele, A. W. Vance. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 19-48; June, 1953.) A critical discussion was presented of recent developments in analog and digital computers and a comparison of their major fields of application. The necessity was stressed for a broader definition of the general subject of information processing. These general definitions and scope of the subject were presented by L. N. Ridenour, who pointed out the relative advantages and disadvantages of analog and digital computers, with the conclusion that ultimate developments in the general field will require "an intimate marriage of analog and digital techniques". The role of analog and digital computers in simulation was discussed by A. W. Vance, who emphasized that so far the simulation of complex systems on a real time base has been accomplished only through the use of analog computing techniques. The limitations of these were discussed, and the important required fields of new developments were outlined, such as more adequate check-out systems and automatic testing of components. An evaluation of basic machine processes was presented by Floyd Steele, who stressed the importance of rationalizing a logical design of all the elements of information processing to provide greater simplification, efficiency and cost reduction. Examples of basic methods of approaching this problem were illustrated. The progress being made in the application of machine computing techniques to the design testing and operation of aircraft was discussed by J.L. Barnes. The problem of increased functional and design complexity of aircraft requiring more elaborate design analysis was stressed. The need for automatic information processing in the operation and testing of aircraft was also discussed.

G. D. McCann

53-52

A Survey of Analogue-to-Digital Converters—Harry E. Burke, Jr. (*Review of Input and Output Equipment Used in Computing Systems, Papers and Discussions Presented at the Joint AIEE-IRE-ACM Computer Conf., New York, N.Y. Dec. 10-12, 1952*, pp. 98-105; March,1953.) This article is an interesting and extensive survey of basic ideas used in analogue-to-digital converters. Definitions are given, various types of coding are discussed, and economical limits of accuracy are stated. While an extensive analogue system is usually accurate to about 1 per cent, conversion to digital data early in the system makes possible economical accuracy of about 0.1 per cent. In most converters, there is a standard in the input against which the unknown quantity is measured, and the output is accomplished by mechanically coded contact closures, coded buses (frequently using vacuum tubes) or coded pulses. The relation of binary action to digital codes is discussed, with examples of the following techniques: direct counting, incremental stepping, commutator and brush, fixed-interval counting of frequency-modulated signals, time measurement, use of a synchronous drum, and null-detection. Details are given of a typical multichannel data-processing system using one of these analogue-to-digital converters. A quasi-static system, in which the operator has control of the situation, is distinguished from a dynamic system, in which the operator controls only the start and must take data for fixed intervals of time thereafter. A detailed bibliography and discussion from the floor following presentation of the paper are given.

Philip R. Westlake

53-53

A Photoelectric Decimal-Coded Shaft Digitizer—W. H. Libaw and L. J. Craig. (*Transactions of the I.R.E.-P.G.E.C.*, vol. EC-2, No. 3, pp. 1-4; September, 1953.) A shaft position to decimal code digitizer utilizing masks and phototubes is described. No associated memory device is needed; each shaft position gives a unique coded set of output signals. Dynamic as well as static readout is thus permitted. The output is decimal and inter-decade ambiguities are prevented through using two masks on all but the the first decade. Devices to operate in octal codes have been designed. An experimental unit is described which utilizes an unusual decimal code. This unit has a resolution equal to 1/100 of a revolution and will operate satisfactorily with shaft speeds up to 10 revolutions per second. Capacity for more than one revolution is achieved through step-down gearing and suitable masks after each step-down.

W. L. Martin

53-54

Multichannel Analog Input-Output Conversion System for Digital Computer—M. L. MacKnight and P. A. Adamson. (*Convention Record of the I.R.E., 1953 Nat. Conv.*, Part 7, pp. 2-6, 1953.) Subject system concerns voltage (200v full scale) to binary digit conversion and vice versa (50v full scale) with intermediate storage and access via magnetic drum. (The system cooperates with an airborne computer.) The system utilizes extensive time sharing of components for nine input and four output channels, as well as automatic calibrations. Conventional voltage to binary digit conversion means are employed, involving accurate sawtooth wave generation with slope automatically calibrated to a reference voltage and a pulse rate, the counting thereof from a reference level to equality of sawtooth and input yields the digitized value of the latter. Inputs are converted serially and recorded on unique drum addresses for computer access. Binary digital outputs of the computer are converted by ingenious means to pulse patterns on the drum, which can be read out in the form of a repetitive assymmetric square wave, the average value of which is proportional to the output binary number. Input frequency limitations and system time lags are discussed. Accumulated inaccuracies of conversion of four parts per thousand are indicated for each type of conversion. Description of a fairly complicated and ingenious system suffers from insufficient diagrams and illustrative material.

W. D. Caldwell

This page has been left blank in order that readers may mount all reviews on cards.

— *The Editor*

53-55

An Analog-to-Digital Converter—A.D. Scarbrough. (*Transactions of the I.R.E.-P.G.E.C.*, vol. EC—2, No. 3, pp. 5-7; September, 1953.) The need to convert shaft position to binary coded information is accomplished by means of an electro-mechanical system utilizing gear trains and cam-controlled switches. Ambiguities are eliminated by the use of two switches on each stage, the particular one read being chosen by the value of the preceding stage. Ambiguity in the first stage is not eliminated, but does offer a unique output which can be easily detected. The configuration permits the use of an indefinite number of cascaded stages for increased capacity. An evaluation of backlash is made which shows the effects to be negligible.

W. L. Martin

53-56

An Analog-To-Digital Converter with an Improved Linear-Sweep Generator—Dean W. Slaughter. (*Convention Record of the I.R.E. 1953 Nat. Conv.*, Part 7, pp. 7-12; 1953.) A theoretical analysis of amplifier characteristics required for an extremely linear-sweep generator is given with extension to practical aspects. Analog-computer techniques have been applied in the design of a sweep generator, making use of chopper stabilized amplifiers for both the positive-going sweep and the sweep-return. Extreme stability of the reference level is obtained, and an automatic self-calibration circuit is described. A voltage comparator based again on a chopper stabilized amplifier is analyzed and described. Conversion of 100 volts full scale to twelve binary digits accuracy is obtained, with sampling rates of fifty per second. Design parameters in considerable detail are given, along with numerous useful references.

W. D. Caldwell

53-57

A Magnetically Coupled Low-Cost High-Speed Shaft Position Digitizer—A. J. Winter. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 203-207; June, 1953.) The output of many precision devices occur as shaft rotations. When accuracy or digital processing is involved, an analog-to-digital conversion must be made. This paper describes a low-cost magnetic shaft position digitizer. It is an A-C carrier device which is electrically stable and mechanically rugged. It has been built to give 1000 and 2000 counts per revolution at shaft speeds from zero to 1800 rpm. The essential elements are two adjacent thin discs 2 inches in diameter, a rotor attached to the shaft to be monitored, and a stator which is a stationary pickup device. An appropriate electrical conducting pattern is etched on opposing faces of the discs. Electromagnetic induction from rotor to stator produces two output voltages in quadrature. The stator voltages go through a discrete null many times per revolution of the rotor. The order in which the two voltages reach a null indicates direction of rotation and determines whether the nulls of one signal are added or subtracted in the accumulator.

C. H. Wilts

681.142 53-58

A High-Speed Product Integrator — A. B. Macnee. (*Rev. Sci. Instr.*, vol. 24, pp. 207-211; March, 1953.) This article describes the use of continuously rotating motor-driven potentiometers with electronic analog differential analyzer computing elements in the evaluation of product integrals. The computing elements are described by the same author in *IRE Proceedings*, Volume 37. In operation, the differential analyzer components are on for 10-millisecond periods 60 times a second. The position of the potentiometers is the parametric variable, y, with t as the variable of integration. A good approximation is obtained in product integration for a series of discrete values, if y varies very slowly with respect to t. In kernel function generation, parameter variation is slow and good values can be obtained. A formula is given for eliminating error in sine and cosine kernels due to the fact that the potentiometer shafts are not stepped from one fixed value to the next during analyzer time-off, but are continuously rotating. Principal sources of error are continuous change of the parametric variable and the fact that no analog multiplier is susceptible to perfect zero adjustment. The article is well documented.

Arthur Dowling

53-59

Linear-to-Logarithmic Voltage Converter—R. C. Howard, C. J. Savant and R. S. Neiswander. (*Electronics*, vol. 26, pp. 156-157; July, 1953.) In this article a linear to logarithmic converter which was developed for a computer requiring a low logarithm base and zero d-c level output is described. Various logarithm bases ranging from 1.13 to 1.78 are available from the circuit using different common twin triode tube types. The unit operates on a modification of the triode circuit which utilizes the logarithmic relationship between grid current and plate current in some triodes operating at low plate voltages. A circuit is shown which has a linear conversion characteristic over a range of input voltages of from 0.3 volts to 300 volts (three log cycles) At the end of the article seven other references are given.

Norman F. Loretz

53-60

Analog Computing with Magnetic Amplifiers Using Multi-phase A-C Voltages—John E. Richardson. (*Convention Record of the I.R.E., 1953 Nat. Conv.*, Part 7, pp. 30-33; 1953.) A new analog computing technique is described and mechanized using magnetic amplifiers. Two dimensional vector representation of sinusoidal voltages is utilized to develop the mathematics necessary for the instrumentation of a computing cell. The magnetic amplifier circuits of the computer are shown. Instrumentations for the solution of several problems are illustrated. The computing cell can be used for multiplication, division, vector resolution, and the solution of many other problems which can be represented in a geometric form. These include direct solutions of the conic sections and solutions by approximation methods of transcendental functions such as trigometric, hyperbolic and exponential.

Joseph A. Fingerett

ANALOG EQUIPMENT

53-61

New Laboratory for Three-Dimensional Guided Missile Simulation—L. Bauer. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 187-195, June, 1953.) A description is given of the Project Cyclone Simulation Laboratory. This laboratory contains an electronic differential analyzer of sufficient size to solve many complex three-dimensional guided missile problems. The article reviews briefly the various types of computing equipment tried, and explains the standardization with REAC computers. A summary is given of the computing equipment available: 13 REAC's, 14 servo units and various pieces of auxiliary equipment. One device of great importance, particularly for coordinate changes, is the D. C. resolver which uses sine and cosine potentiometers of high accuracy. Approximately 30 of these are provided in the various servo units. A short discussion is given of operating procedure. This is necessarily brief since the computer has been in operation only since October 1952.

C. H. Wilts

681.142 53-62

Numerical Determination of Biharmonic Functions by an Analogue Method using Superposed [resistor] Networks — J. Boscher. (*Comp. Rend. Acad. Sci.* (Paris), vol. 236, pp. 44-46; Jan. 5, 1953.) Description of the network used and of its application to the determination of Airy's function.

Courtesy of *Proceedings of the I.R.E.* and *Wireless Engineer.*

This page has been left blank in order that readers may mount all reviews on cards.

— *The Editor*

681.142:538.691 53-63

Analogue Computer for Study of Trajectories in Electron Lenses — A. Hampikian. (*Compt. Rend. Acad. Sci.* (Paris), vol. 236, pp. 1864-1866; May 11, 1953.) Description of a computer comprising an 8-stage network based on principles given by Grivet and Rocard (2810 of 1950), and of its use in determining the parameters of magnetic electron lenses.

Courtesy of *Proceedings of the I.R.E.* and *Wireless Engineer.*

681.142 53-64

A Five-Channel Analog Correlator — M. J. Levin and J. F. Reintjes. (*Tele-Tech,* vol. 12, pp. 70-72, 125; March, 1953.) The operation and circuit details of equipment which determines simultaneously five points on the correlation curve of a time series and displays the approximate curve on a cro are described. The value for the time increment can be set between 1 and 400 μs by adjusting the rate at which the sampling-pulse generator is triggered.

Courtesy of *Proceedings of the I.R.E.* and *Wireless Engineer.*

53-65

An Analogue Computer Employing the Principle of the Kelvin Bridge—V. I. Little. (*Phys. Soc. Proc.*, vol. 66B, pp. 185-188; Mar. 1, 1953.) A special purpose computer to solve for $\propto$ in the equation

$$\frac{\cosh 2 \propto S_1}{\cosh 2 \propto S_2} = A$$

with S_1, S_2, A as experimentally determined constants is described. A Master Curve is plotted for y = log Cosh x with y vertical and x (corresponding to 2 $\propto$ s) horizontally. A wire is cemented to the curve and acts as a contact between two horizontal slide wires spaced A units apart. The wires are interconnected in the form of a kelvin bridge with external decade boxes for ratio setting. At the point of balance the ratio of length of slide wires is equal to the decade ratios which have been set equal to $\frac{S_1}{S_2}$, $\propto$ may be determined to about 0.2%. The two major errors are: errors in matching slide wire to curve and errors in uniformity of slide wires. This is a hand operated device.

T. A. Rogers

53-66

An Electrical Computer for the Solution of Linear Simultaneous Equations — A. Many, U. Oppenheim, and S. Amitsur. (*Rev. Sci. Instr.*, vol. 24, pp. 112-116; Feb., 1953.) The matrix-diagonalizing network of this computer is described in previous articles in Volumes 18 and 21 of the *Review.* This article develops the theory of the network. This computer realizes the given set of equations, and solutions are found directly (not obtained by convergent iteration). To determine solutions without disturbing the network, derived voltages, rather than those which directly realize the solutions, are measured. An oscilloscope is used as a null-indicator and parameters are varied until the voltage derived from a potentiometer is made equal in magnitude and phase to the voltage of interest. The oscillograph is used to balance an output voltage with that derived from the potentiometer. A simple correction formula is applied to eliminate error due to losses in the coils.

Solution time depends on the precision desired. Accurate adjustment of condensers takes most of the time. When a precision of one part in a thousand is desired, a set of nine equations takes about one hour. To solve the same set with a precision of one part in 100 takes about 20 minutes.

Arthur Dowling

681.142 53-67

A Fourier Analyzer—F. J. McDonal. (*Rev. Sci. Instr.*, vol. 24, pp. 272-276; April, 1953.) This Fourier analyzer was developed to facilitate acceptance of multichannel recordings by an analog computer, since conversion of information from conventional oscillographs is unduly difficult. In analysis of transients, this unit generates $F(t)$ from variable-area film, generates cos t and sin t, multiplies them respectively by $F(t)$, and integrates the product over an interval for which $F(t)$ has a finite value. $F(t)$ is generated by photoelectrically sensing the film through a feedback amplifier with cathode-follower output. Sine and cosine functions are generated mechanically. Functions are multiplied by the potentiometer method and put through a servo integrator. In seismic research, for which this analyzer was developed, it is often desirable to analyze phenomena over a selected short interval. A timing circuit accepts signals (markers placed at beginning and end of the desired interval) from a photocell which start and stop integration. A comparison of this equipment's analysis of a wave form with experimentally obtained values for the same wave shows agreement for the most part within 0.2 per cent.

Arthur Dowling

53-68

The Nordsieck Computer—A. Nordsieck. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 227-231; June, 1953.) This paper describes a compact rugged mechanical differential analyzer, accurate to about one part in a thousand. The basic component of the machine is an improved ball and disc integrator which will transmit an appreciable torque without slipping. It can therefore be used in a mechanical differential analyzer without the torque amplifiers of the Bush type computer. A detailed description is given of this mechanism. In addition to the usual integrators, adders, input-output plotting tables, etc., each computing assembly contains a plug-board for interconnecting the components electrically by use of selsyn motors. The simplicity associated with this method of interconnection permits the rapid establishment of different problems on the machine.

C. H. Wilts

UTILIZATION OF ANALOG EQUIPMENT

53-69

A New Concept in Analog Computers—Lee Cahn. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 196-202; June, 1953.) The first part of this paper is devoted to a discussion of the economics of computer operation. The most important factors considered are initial cost, complexity, accuracy, speed, reliability and technical knowledge required of the operator. It is pointed out that the pattern of use depends to a large extent on many of these factors, and in particular that there is a wide field of use for computers of low initial cost, although they be of only moderate accuracy. The second part gives a brief description of such a low cost computer, the EASE, manufactured by Beckman Instruments.

C. H. Wilts

53-70

The Solution of Partial Differential Equations by Difference Methods Using the Electronic Differential Analyzer — R. M. Howe and V. S. Haneman. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 208-226; June, 1953.) Partial differential equations can be approximated by systems of simultaneous ordinary differential equations by replacing one or more of the partial derivatives by the appropriate finite differences. The resulting systems of equations can sometimes be solved directly by an electric analog computer employing passive circuits as well as feedback amplifiers, or by an electronic differential analyzer amploying only feedback amplifiers. The greatest advantages of the latter type seem to be increased accuracy and the possibility of operation at slower speed. There are undoubtedly some problems in which these outweigh the greater simplicity of the electric analog computer. Both theoretical analysis of the accuracies attainable with the difference method and actual solution examples are described. Among those problems considered are one dimensional heat flow and lateral vibration of beams. A description is given of an 80 amplifier analyzer to be installed at the University of Michigan.

C. H. Wilts

This page has been left blank in order that readers may mount all reviews on cards.

— *The Editor*

681.142 53-71

Analog Computer Solves Geophysical Problems—S. Kaufman. (*Electronics*, vol. 26, pp. 174-177; June, 1953.) The article begins by noting the many calculations necessary in problems encountered in geophysical exploration. However, the computer described is not restricted to geophysical problems alone but may be used to solve types where, given a large set of values of initial data and a smaller set of coefficients, it is desired to pair each coefficient with a selected member of the large set of numbers, multiply each pair of terms, and sum the products. Input data is stored on a large jack board as a voltage proportional to a measured field strength at a particular test point. A plug board selects the desired set of input data for computation. Read out is direct from electronic counter-chronographs which accept pulses from a voltage comparator, the time spacing between pulses being determined by the magnitude of the voltage input to the comparator. A photograph of the unit and schematics of the comparator, input and control units are shown. The operation of the input and control units, voltage comparator and counter-chronographs is explained.

Norman F. Loretz

DIGITAL COMPONENT RESEARCH

53-72

Quarterly Report No. 11—John R. Bowman, F. A. Schwertz, et al. (*Quart. Rept. Computer Components Fellowship Mellon Inst.*, April 11, 1953, to July 10, 1953. 132 pp.) Quarterly Progress Report No. 11 contains seven sections as follows: I. The Design of Nonlinear Resistor Function Switches, II. Nonlinear Semiconductor Resistors, III. Bistable Optical Elements, IV. Saturable Transformers as Gates, V. Printed Circuitry Via Xerography, VI. Electroluminescence, VII. Electrical and Optical Properties. The first section deals with the possibility of replacing crystal diodes by nonlinear resistors in certain logical switching operations. Section II has to do with the a.c. and d.c. properties of nonlinear semiconductor resistors. Section III contains some information on the problems and techniques involved in building a binary digit storage tube comprising a photocathode and a phosphor anode in an evacuated glass envelope. A discussion of the use of ferromagnetic ferrites as switching and gating elements in digital circuitry is included in Section IV. Section V comprises a first report on the feasibility of employing the Xerographic technique for the fabrication of printed circuits. Section VI contains an initial report on the fabrication and evaluation of electroluminescent light sources.

F. A. Schwertz

621.392.5:538.652:681.142 53-73

Magnetostrictive Sonic Delay Line — H. Epstein and O. Stram. (*Rev. Sci. Instr.*, vol. 24, pp. 231-232; March, 1953.) This describes a recirculating storage unit using a thin-wall Ni tube as the magnetostrictive element, with suitable transducer coils enclosed in ferrite cups whose length is adjusted to correspond to the half wavelength of a 600-kc vibration in the Ni Tube. Experimental delay lines giving delays of 100 μs and 800 μs have been constructed. Operational characteristics are listed.

Courtesy of *Proceedings of the I.R.E.* and *Wireless Engineer.*

53-74

The Univac Tube Program — T. D. Hinkelman and M. H. Kraus, *Transactions of the I.R.E. — P.G.E.C.*, vol. EC-2, No. 3, pp. 8-12; September, 1953.) This article describes the experience to date with tube failures in the four Univacs so far constructed. The per cent failures per 1000 hours of operation are given for the 25L6 tube (the tube that is used most frequently in the Univacs) and for all tubes combined (including the 25L6, 6AK5/5591, 7AK7, 28D7, 6AL5, 6AN5 and 6BE6/5915). It is shown that the failure rate for Univac No. 4 is about 1/7 (½ per cent per 1000 hours) of that for Univac No. 1. This reduction is attributed to the program of selection, design, inspection and maintenance that has been carried out for the Univac tubes. The criteria for selecting the particular tube types, the philosophy of their circuit design (although circuit diagrams are lacking) and the design problems that appeared during operation, the inspection tests for incoming tubes and the maintenance procedure which detects 80 per cent of all tube failures during maintenance periods are described. The success of this program will be well proven if the authors' prediction of 0.1 per cent *operational* failures per 1000 hours in Univac No. 4 is achieved.

David F. Rutland

53-75

Components of Digital Computers — E. C. Johnson. (*Industrial Mathematics*, vol. 3, pp. 92-103; 1953.) The paper begins with a brief discussion of the distinguishing features and general logical organization of modern digital computers. Binary arithmetic is introduced as the commonly used language of computing machines, and the distinction is made between serial and parallel modes of operation. Then in simple terms some of the techniques and components most frequently found in present day computers are described. Included are flip-flops, counters, high speed switches, magnetic drums, acoustic-delay lines, and electrostatic storage tubes.

S. Conte

53-76

Magnetic Shift Register Using One Core Per Bit—R. D. Kodis, S. Ruhman, and W. D. Woo. (*Convention Record of the I.R.E., 1953 Nat. Conv.*, Part 7, pp. 38-42; 1953.) The principle of the two magnetic core per bit shift register is reviewed. A one core per bit register is described which makes use of a condenser for temporary storage during read-out. The operation of the circuit is clearly explained. The register requires only one shift pulse which is applied in series to all cores of the register. The circuit, in addition to a magnetic core, contains a diode, a condenser and a resistor. An approximate analysis of the circuit is given and all assumptions are stated. Waveforms of a register operating at a 16 K.C. shift frequency are presented. The register has been operated at a 100 K.C. shift frequency and in cascades up to 50 stages.

Raymond Davis

53-77

Engineering Experience in the Design and Operation of a Large Scale Electrostatic Memory—J. C. Logue, A. E. Brenneman and A. C. Koelsch. (*Convention Record of the I.R.E., 1953 Nat. Conv.*, Part 7, pp. 21-29; 1953.) This article describes the salient features of an electrostatic memory designed for the IBM 701 calculator. Adequate discussion of the mode of operation of the storage tubes is given together with diagrams of various voltage waveforms applied to the tubes. Of interest is the manner in which two storage tubes are operated together and made to share a single amplifier for read-out and regeneration. The design of the video amplifier is treated in some detail and the importance of a good noise figure is stressed. The cathode ray beam deflection circuits are discussed and circuit diagrams given. Little or slight mispositioning of the beam traceable to power supply noise was found to have an adverse effect on the read-around ratio. A claim for the discovery of a "new effect" is made. This effect, baptized a "Mudhole", is assigned to bombardment-induced conductivity of the phosphor screen. The authors conclude that the cathode ray tube storage system has been established as a very satisfactory memory system.

R. Thorensen

534.13 53-78

Diffraction Patterns for Solid Delay Lines—R. A. Mapleton. (*Jour. Acous. Soc. Amer.*, vol. 25, pp. 516-524; May, 1953.) Solutions of the vector equation of equilibrium for an isotropic solid are presented for the special case of loss-free sine waves. Examples are considered in which the distribution of a single stress component is selected to simulate the stress produced by a HF quartz crystal.

Courtesy of *Proceedings of the I.R.E.* and *Wireless Engineer.*

621.396.6:681.142 53-79

Circuitry "Packages" for Electronic Computers—(*Tech. Bull. Nat. Bur. Stand.*, vol. 37, pp. 36-37; March, 1953.) This is a short description of etched-circuit mass-produced units, 7x3.5x1 in., with projecting pin connections. The basic unit comprises a transformer-coupled pulse amplifier using a Type-6AN5 miniature beam-tetrode and a number of Ge diodes. Four

This page has been left blank in order that readers may mount all reviews on cards.
— *The Editor*

variants of the basic unit meet most computer-circuit requirements. A new computer including 800 such units is under construction. Test jacks facilitate location of defective units and of defective components of individual units. Courtesy of *Proceedings of the I.R.E.* and *Wireless Engineer.*

53-80

Design of Triode Flip-Flops for Long-Term Stability—J. O. Paivinen and I. L. Auerbach. (*Transactions of the I.R.E.—P.G.E.C.*, vol. EC-2, No. 2, pp. 14-26; June, 1953.) This article (rather lengthy because of a lot of circuit analysis) gives design equations for an Eccles-Jordan flip-flop circuit. The particular flip-flop circuit that the authors are most concerned with is one using triode tubes in which the grids are clamped both positively and negatively by diodes, although equations are also given for a flip-flop without the diodes. The effect of bleeder resistors from the plates and a common cathode resistor are also analyzed. The final design equations take into account resistance and voltage supply tolerances and yield values of the tube plate resistance and the flip-flop circuit parameters for a particular plate or output and grid voltage swings. Detailed discussions of the effects of varying the circuit parameters are given to aid in the design of a flip-flop for any specific application. A numerical example helps to clarify the design procedure. The analysis is for steady-state conditions only and does not include the switching time or a.c. stability of the circuit.

David F. Rutland

53-81

Coincidence Technique for Getting Decade Scaling from Binary Flip-Flop Counters—R. Parshad and A. Sagar. (*Rev. Sci. Instr.*, vol. 24, pp. 542-544; July, 1953.) This article presents four decade-counter circuits, negative-triggered, realized by using coincidence of two or more flip-flops to trigger a more significant stage. This triggering acts as a blocking signal to prevent triggering one or more of the remaining flip-flops, and the count is advanced by more than 1. The four schemes can be seen more readily by substituting for the authors' symbols *o* and *e*, respectively, the 1 and 0 conventional in this country. The schemes work out as follows: I. Coincidence 00*11* triggers 2^2, which blocks triggering of 2^1, with the result 0110; coincidence 0*111* triggers 2^3, which blocks triggering of 2^2, with the result 1110. II. Coincidence 0011 triggers 2^3, which blocks triggering of 2^1, with the result 1010. III. Coincidence 0*101* triggers 2^3, which blocks triggering of 2^2, with the result 1100. IV. Coincidence 0*111* triggers 2^3, which blocks triggering of 2^1 and 2^2, with the result 1110. Aside from these "skips" the operation is straight binary counting.

Arthur Dowling

53-82

The Snapping Dipoles of Ferroelectrics as a Memory Element for Digital Computers — C. F. Pulvari. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 140-159; June, 1953.) The storage properties of ferroelectric materials are reviewed. Signals produced by change in polarization are discussed and experimental results on reminant polarization are given. Variability of sensitivity of condensers made from the same ceramic sheet is mentioned. Bistable circuit elements and memory matrix arrangements are described.

H. D. Huskey

53-83

Nonlinear Resistors in Logical Switching Circuits—F. A. Schwertz and R. T. Steinback. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 174-186; June, 1953.) See Review 53-17, September issue.

53-84

Magnetic Reproducer and Printer — J. C. Sims, Jr. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 160-166; June 1953.) A new process for producing printed copy by magnetic means is described. The information is recorded on a magnetically sensitive plate, and developed with a magnetic ink. The image can then be transferred to paper and fixed. This ferrographic process has been employed in the design of a duplicating machine and has been studied for high-speed-data printing operations. Multichannel magnetic heads with 100 channels per inch have been produced and recording speeds in excess of 10,000 characters per second are expected.

H. D. Huskey

53-85

An Improved Cathode Ray Tube Storage System — R. Thorensen. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.* pp. 167-173, June, 1953.) A new mode of operation of a cathode ray tube memory which minimizes the effects of "flaws" and gives substantial improvement in "read-around-ratio" is described. Tubes that were retired from service in a conventional Williams' tube system for poor read-around ratio showed factors of improvement of three or four under this new system. The new system gates on the negative "dash" signal instead of the initial positive "dash" signal.

H. D. Huskey

DIGITAL SYSTEMS RESEARCH

53-86

The Processing of Information-Containing Documents — George W. Brown and Louis N. Ridenour. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 80-85, June, 1953.) The application described in this paper is concerned with the task of processing not only information, but also the original documents that contain it. Sorting, collating, selecting and other processes are performed automatically on the documents, while the information they contain can at the same time be handled by familiar digital techniques. This type of processing is attained by attaching to the document a paper tape on which is recorded, in a form which the digital machine can read, the information needed to perform the processing of the document. More than 10,000 documents of all sorts can be processed per hour by a single machine, which makes no demands on the size, shape, thickness, flatness or degree of preservation of the documents being handled. The new techniques may be applied to the clearing of bank checks, posting and sorting of department store or oil company charge slips.

E. C. Nelson

DIGITAL EQUIPMENT

53-87

An Introduction to High-Speed Digital Computation — W. F. Bauer. (*Industrial Mathematics*, vol. 3, pp. 13-22, 1953.) In this paper the author deals with the organization and uses of large-scale, high-speed digital computers, with particular emphasis on the programming of problems for such machines. After discussing arithmetic operations in the binary number system and the various types of memory devices in common use, he presents in some detail the major characteristics of MIDAC, the University of Michigan Computer. MIDAC has an acoustic-type memory of 512 cells, each cell consisting of 45 binary digits. It is a 3-address machine and has a total of 16 operations which it can perform. The author illustrates the operation of MIDAC with a simple code for the function cos x. He concludes by mentioning some of the most important applications of large-scale computers in the scientific and business world.

S. Conte

681.142 53-88

Moderne Mathematische Maschinen — L. Bierman and H. Billing. (*Naturwissenschaften*, vol. 40, pp. 7-13, Jan. 1953.) (In German) The paper consists of four sec-

This page has been left blank in order that readers may mount all reviews on cards.

— The Editor

ions titled respectively: History; Program equenced arithmetical machines; and the ottingen machines G(1) and Logical mahines G(2). The first three of these secions are brief intelligent discussions of aterial already well reviewed in a umber of American journals and certain- y very well known to all computer eople in this country. The last section s essentially a description of the G(1) achine built in Göttingen recently. The (2), a machine stated to be ten times s fast as the G(1), i.e., having an operaion speed comparable to American agnetic drum computers, is briefly lluded to but not fully discussed. The (1) machine appears to be largely ntended as a pilot model for the much arger and faster G(2). Both machines re magnetic drum serial type machines hich accept decimal numbers from teleype but operate internally on the binary ystem. The G(1) can store only 26 useul numbers of 32 binary digits each. All umbers stored must be between plus and inus eight in value. Commands cannot e stored on the drum but are executed s they pass through one of several eletype readers sequentially. Although he G(1) does not have a conditional ransfer command, it does have a square oot command built in. A command table or G(1) is given. G(1) is presumably a ingle address machine.

J. Weizenbaum

81.142 53-89

Present Development of Programme-Controlled Computers in Germany — G. Overhoff. (*Phys. Blätter*, vol. 9, pp. 31-36; Jan., 1953.) Details are included of electronic machines under development at the Darmstadt Technische Hochschule and in the Max-Planck-Gesellschaft Institute at Göttingen, and of commercial em-relay machines.

Courtesy of *Proceedings of the I.R.E.* and *Wireless Engineer.*

53-90

IBM Magnetic Tape Reader and Recorder — W. S. Buslik. (*Review of Input and Output Equipment Used in Computing Systems, Papers and Discussions Presented at the Joint AIEE-IRE-ACM Computer Conf., New York, N.Y. Dec. 10-12, 1952*, pp. 86-90, March, 1953.) The magnetic-tape reader-recorder described in this article accelerates ½-inch tape to 75 inches per second in about 5 milliseconds. The tape transport problem is essentially broken up into two parts: the handling of tape in the vicinity of the read-write and erase heads, and the handling of the reels, which give or take up slack to tape loops which act as buffers to make the acceleration requirement of the reels less stringent than that of the tape. The tape-acceleration mechanism is described in detail. It consists of two symmetrical drive mechanisms, each actuated by an idler which engages a continuously rotating capstan. Motion of the idler is effected by combination of a right-left magnet with a fast-acting loudspeaker-type upward-moving coil. On each reel shaft are three clutches of the magnetic-powder type for forward, reverse and stop. They are operated as on-off servos by vacuum-type pneumatic switches arranged so that the slack loop of tape remains in the middle third of a column which is kept evacuated on the under side of the tape. Head construction, alignment adjustments and start-stop instrumentation are briefly described.

Philip R. Westlake

53-91

EDVAC Drum Memory Phase System of Magnetic Recording — Donald Eadie. (*Elec. Eng.*, vol. 72, pp. 590-595; July, 1953.) This article describes a 10,000 word magnetic drum which has been coupled to EDVAC. The drum is synchronized to EDVAC by a servo-mechanism which compares pulses from a photocell (scanning a synchronizing wheel on the drum), to pulses generated by EDVAC. Words coming from EDVAC at a 1 Mc bit rate are split into 6 bands on the drum. This is done in such a way that the drum can accept them (and later reproduce them) at the 1 Mc rate, and still record at 166 kc and 80 cells per inch in any one band. The recording circuitry feeding the heads acts like return-to-zero circuitry, but produces a flux pattern similar to non-return-to-zero recording with a superimposed ripple. The read-back circuitry makes use of the phase relationships of these ripples to aid in the reproduction of the written information.

Harry Larson

53-92

RAYDAC Input-Output System—Walter H. Gray. (*Review of Input and Output Equipment Used in Computing Systems, Papers and Discussions Presented at the Joint AIEE-IRE-ACM Computer Conf., New York, N.Y. Dec. 10-12, 1952*, pp. 70-76; March, 1953.) This second article on the RAYDAC computer describes the mechanisms for entering original information onto magnetic tapes, and for printing out results from magnetic tapes. A Problem Preparation system, which is separate from the main computer, uses two modified Teletype units with paper tape punching equipment, and a paper-tape to magnetic-tape converter. To guard against human error, two paper tapes are prepared from the same data, the second being automatically compared with the first. Details are given on the Output Printer system, also a separate unit, in which a modified Teletype machine prints results in octal or decimal notation from the magnetic tape. Format contrals, included in this output system, are described.

R. G. Canning

53-93

SEAC Input-Output System—S. Greenwald, James L. Pike, Ruth C. Haueter, Ernest F. Ainsworth. (*Review of Input and Output Equipment Used in Computing Systems, Papers and Discussions Presented at the Joint AIEE-IRE-ACM Computer Conf., New York, N.Y. Dec. 10-12, 1952*, pp. 31-46, March, 1953.) After Mr. Greenwald's survey of the system, Mr. Pike describes in more detail the plug-in wire cartridges used for input and output, and the reel-less tape drives used for auxiliary memory. Miss Haueter describes a paper-tape-to-wire unit called the inscriber, and a wire-to-paper-tape unit called the outscriber, both of which operate separately from the computer. Finally, Mr. Ainsworth summarizes the generally favorable operating experience obtained from these relatively simple devices.

Robert D. Elbourn

53-94

Magnetic Tape Recording Techniques and Performance—H. William Nordyke, Jr. (*Review of Input and Output Equipment Used in Computing Systems, Papers and Discussions Presented at the Joint AIREE-IRE-ACM Computer Conf., New York, N.Y. Dec. 10-12, 1952*, pp. 90-94, March, 1953.) This paper gives characteristics and performance data of the production prototype magnetic-tape units of the IBM 701 Electronic Data-Processing Machine. A non-return-to-zero recording method which changes the flux from saturation at one polarity to saturation at the other every time a binary 1 occurs is used. The write circuit uses two tubes, switched on alternately by means of a flip-flop. Each tube conducts current to one side of a split magnetic-head winding. The read circuit uses a push-pull amplifier followed by a clipper, rectifier and pulse-shaping circuits, with the same magnetic-head winding used in the write circuit. The clipper rejects all signals below 20 per cent of the average peak level and accepts all signals above 25 per cent of the average peak level. The two main types of tape errors, pulse dropouts and interference pulses are discussed in detail. Detailed analysis of tape defects is given in the form of charts, tables and statistics. Difficulties of tape-splicing and the preparation of error-free lengths of tape are described. A lengthy discussion of the entire IBM tape setup concludes the article.

Philip R. Westlake

53-95

The RAYDAC System and Its External Memory—Kenneth M. Rehler. (*Review of Input and Output Equipment Used in Computing Systems, Papers and Discussions Presented at the Joint AIEE-IRE-ACM Computer Conf., New York, N.Y.*

This page has been left blank in order that readers may mount all reviews on cards.
— *The Editor*

Dec. 10-12, 1952, p. 63-70, March, 1953.) This article, the first of three on the RAYDAC system, gives a brief description of the computer, followed by a more detailed factual description of external memory operation, the magnetic type medium, external memory performance and some design recommendations. Information is recorded on magnetic tapes by means of a separate unit, after which it is fed into the computer by the external memory units. The author refers to (and summarizes) some of the pioneer work done by Raytheon in the field of reliable operation of digital tape recorders. The value of transfer weighted count checking employed in the computer, as a piece of system test equipment, is emphasized.

R. G. Canning

53-96

High-Speed Printing Equipment — L. Rosen. (*Review of Input and Output Equipment Used in Computing Systems, Papers and Discussions Presented at the Joint AIEE-IRE-ACM Computer Conf., New York, N.Y. Dec. 10-12, 1952*, pp. 95-97; March, 1953.) This article describes the Synchroprinter, which was developed to provide rapid print-out (600 characters per second) for electronic computers. It consists of a rotating cylinder containing the type for decimal digits in bands around its circumference. The cylinder is synchronized with a sync pulse generator which produces a pulse in one of ten coils when the digit to be printed is in position to be struck by one of the print hammers along the axis of the cylinder. There is also an alphanumeric version of the printer, containing 36 characters on each type band. Some details of the circuitry are given. An electronic counter, which may be used for both counting and sensing coincidence in the count, triggers a thyratron causing the hammer to strike the paper against the print cylinder. Although the model described prints only 40 characters per line, it was considered reasonable to extend the same design technique to 120 characters per line, which would print 1,800 characters per second. The use of special characters in type to facilitate graph plotting is also discussed.

Philip R. Westlake

53-97

Engineering Organization of Input and Output for the IBM 701 Electronic Data-Processing Machine—Louis D. Stevens. (*Review of Input and Output Equipment Used in Computing Systems, Papers and Discussions Presented at the Joint AIEE-IRE-ACM Computer Conf., New York, N.Y. Dec. 10-12, 1952*, pp. 81-85; March, 1953.) This article describes, with the inclusion of block diagrams, the card-reader, the card-recorder, the alphabetic printer, the high-speed (75 inches per second) magnetic-tape reader-recorders (four are used) and the manual input-output of the 701 system. The system selects units for reading, writing or rewinding; provides interlocks; reads from and writes in the electrostatic memory and the input-output units; provides synchronism; and disconnects units when the transfer of information is finished. Electrostatic storage of information in a form referred to as a "card image" facilitates the use of card input and output. The card-reader handles 150 cards a minute, the card-recorder 100 a minute. The alphabetic printer puts out 150 lines a minute, 120 characters to the line; 48 characters are available. The reader, recorder and printer are all modified IBM accounting machines. The magnetic-tape reader-recorders store 100 bits to the inch on each of seven tracks (one used for an "odd-even check"). They read or write 1,250 36-bit words a second. From the stopped position, the access time to the next unit is 10 milliseconds.

Philip R. Westlake

53-98

Miniature Universal Calculating Machine — (*Engineering*, vol. 175, No. 2539, pp. 102-106; Jan. 23, 1953.) This article describes the mechanism of the small mechanical calculator (similar to desk calculators) invented by C. Herzstark and manufactured by Contina, Limited, Liechtenstein. It is sold under the trade name *Curta*. The calculator is small enough to be held in the hand and weighs eight ounces. The machine may be used to perform the four arithmetic operations, square roots, cube roots and other common calculations. It is designed in the form of a cylinder. This design permitted a single step drum to actuate successively each digit setting of the machine, instead of an individual drum for each setting. There is only one direction of rotation of the drum, whether the operation be addition or subtraction. The step drum has nineteen rows of gear teeth on its circumference. Each row has a number of teeth ranging from one to ten. Nine rows are for addition, and nine rows carry the complementary digits of the addition rows, since subtraction is accomplished by adding the complement. The axle of digit number one has an additional cog wheel which is struck by the top row of ten teeth when subtracting. The complement is corrected in this way. Calculations are performed by driving the drum past each of the setting wheels to transfer a number corresponding to the number of teeth encountered. Eight place multipliers can be used with a maximum of eleven places in the answer. The calculator has a number of locking devices which prevent it from being wrongly used. The device is an ingenious mechanical design and is truly a miniature calculating machine. The article is well illustrated with pictures and diagrams of the major components of the machine.

Raymond Davis

DIGITAL COMPUTER UTILIZATION

53-99

Diagnostic Programs and Marginal Checking in the Whirlwind I Computer — Norman L. Daggett and Edwin S. Rich. (*Convention Record of the I.R.E., 1953 Nat. Conv.*, Part 7, pp. 48-54, 1953.) Faults in the Whirlwind I Computer are classified into the following four categories: (1) gradual deterioration; (2) sudden failures; (3) intermittent failures; and (4) maladjustments in newly-installed equipment. A regular procedure of marginal checking is followed to locate gradual deterioration of components. D-C supply voltages are varied in small sections of the computer at a time, and a record is kept of the tolerable margin. When it drops below a specified limit, further investigation is carried out and the failing components are replaced. Sudden failures are the most easily located by special programs and cyclic program control. Intermittent failures are difficult to trace; their detection usually depends on a study of all reports on recent transient failures, photographs of indicators and controls taken following errors, and observations of engineers and technicians. Tapping on components or panels suspected is very helpful when the failures are caused by shorts. Maladjustments in newly-installed equipment are found by all the methods used for the other types of faults. Since it is more practical in this computer to repair faulty circuits in place than to substitute spare panels, it is always necessary to isolate a fault completely.

R. Lipkis

UTILIZATION OF DIGITAL EQUIPMENT

53-100

Operating Experience with RAYDAC—Franklin R. Dean. (*Review of Input and Output Equipment Used in Computing Systems, Papers and Discussions Presented at the Joint AIEE-IRE-ACM Computer Conf., New York, N.Y. Dec. 10-12, 1952*, pp. 77-79, March, 1953.) The last in a series of three articles on the RAYDAC is concerned with the results of the acceptance tests performed on the computer at Raytheon, before it was dismantled for shipment to its permanent location. Phase 1 tests involved the individual operation of input and output equipment, central control and internal memory, external memory and the arithmetic unit. The lengths of error-free runs during the tests are indicated. Phases 2 and 3, concerned with the solution of equations, are mentioned briefly. The rather unique self-checking features of the machine are described, including a list of the error diagnosis indications available to the operator.

R. G. Canning

This page has been left blank in order that readers may mount all reviews on cards.
— *The Editor*

53-101

Checking Circuits and Diagnostic ꞌoutines — J. Presper Eckert, Jr. (*Con- ention Record of the I.R.E., 1953 Nat. ꞌonv.*, Part 7, pp. 62-65, 1953.) The hecking routines used with ENIAC are lescribed and their weaknesses evalu- ated. Reasons for turning to built-in hecking in BINAC and UNIVAC are resented and a short verbal description f the checking circuits is given. This aper is labeled a defense of built-in utomatic checking. It is an excellent lefense, but it is not a proper weighing f the relative merits of checking ircuits versus checking routines. It nust be read in conjunction with a lefense of checking routines to provide true evaluation of the checking problem.

E. C. Yowell

53-102

Diagnosis and Prediction of Malfunc- ions in the Computing Machine at the nstitute for Advanced Study—G. Estrin. (*Convention Record of the I.R.E., 1953 Nat. Conv.*, Part 7, pp. 59-61, 1953.) A rief description is given of the char- acteristics of the computer, including he safety factors on the components. rediction of malfunctions includes a "short-term prediction," consisting of laily routine tests of safe memory stor- age, input-output, multiplication, divi- ion, a complex diagnostic code, and a "noise observer"; and a "long-term rediction," consisting of biweekly or nonthly spill tests, memory parameter ptimization, power supply and regulator bservation, tests of gate toggle combi- ations, and replacement and test of ubes with 5000 hours of operation. All omputations are run twice and their greement checked by memory sums. Diagnosis is facilitated by scanning of ubes, the diagnostic code, modification f programs and observation by oscillo- scope. An accurate history of operation s maintained, and is helpful in diagnos- s and in evaluation of diagnostic tech- niques.

R. Lipkis

53-103

Commercial Applications—The Impli- ation of Census Experience—James L. McPherson. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 49- 3; June, 1953.) The Bureau of Census as operated a UNIVAC System for the abulation of census statistics since April, 1951, twenty-four hours a day, even days a week. This application of he electronic computer approximates ccounting types of applications. On the asis of Census experience specific tatements concerning the commercial pplicability of electronic digital com- uters are made. (1) They are more effi- ient than any other tool presently avail- ble for many commercial purposes. 2) They are not ideally balanced for commercial applications. Their arith- metic power exceeds their input and output power. (3) It is expected that digital computers will evolve into power- ful tools for commerce and industry just as did punched card equipment which was first developed for census problems.

E. C. Nelson

53-104

Automatic Data Processing in Larger Manufacturing Plants—M. E. Salveson and R. G. Canning. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 65-73; June, 1953.) In medium and large manufacturing plants (over 500 employ- ees) the volume of details involved in the production itself is very large. With the advent of the electronic data handl- ing systems, the possibility exists for a more efficient production control system. This paper reports on a project spon- sored by the Office of Naval Research on "Production Planning and Schedul- ing", which includes the systems de- sign specifications for automatic data handling equipment for production control. To determine system requirements, sur- veys have been conducted at individual plants throughout the country. A block diagram of a possible system, along with the possible design philosophy, is presented.

E. C. Nelson

53-105

Payroll Accounting with ELECOM 120 Computer—Robert F. Shaw. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 54-64, June, 1953.) This paper reports an applications study of the ELECOM 120, a decimal computer of moderate cost, to the processing of the weekly payroll for an organization of 4,000 to 5,000 employees. The computer draws data from both magnetic tape and paper tape, and computes earnings, deductions, and net pay, producing a new magnetic tape containing data from the old account tape but with cumulative totals corrected to date. One computer- controlled typewriter prepares pay checks, and another types itemizes statements, simultaneously producing a carbon copy which forms a payroll journal. All the computer operations, including typing of checks and state- ments, require approximately 30 sec- onds per employee.

E. C. Nelson

53-106

Requirements of the Bureau of Old- Age and Survivors Insurance for Elec- tronic Data Processing Equipment — Edward E. Stickell. (*Proc. Western Com- puter Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 74-79; June, 1953.) This is a report on the investigations made by the Bureau of Old-Age and Survivors Insurance, Social Security Administration, of appli- cations of electronic data processing equipment. The type of equipment in question would deal with the establish- ment, maintenance and reference uses of records of the identities and the earnings of approximately 100 million individuals now holding account number cards issued under the Old-Age and Survivors Insurance provisions of the Social Security Act, as amended. The possibili- ties and limitations of card-to-tape and tape-to-card equipment for sorting data in electronic media, and the present lack of equipment for high-speed random access to data stored outside the machine are discussed.

E. C. Nelson

53-107

Experience with Marginal Checking and Automatic Routining of the EDSAC— Maurice V. Wilkes, Montgomery Phister, Jr., and Sidney A. Barton. (*Convention Record of the I.R.E., 1953 Nat. Conv.*, Part 7, pp. 66-71; 1953.) The introduc- tion of pulse attenuations as a marginal checking method is described with circuit diagrams. The application of small d.c. voltages to change the characteristics of the amplifiers is also presented. It is remarked that this system may be of more use in correctly adjusting the amplifiers than in check- ing deterioration of components. An automatic method of putting these various tests on the machine is described in the Automatic Routining section.

E. C. Yowell

ORIENTATION READING

53-108

New Equations for Management—J. E. Hobson. (*Proc. Western Computer Conf., Joint IRE-AIEE-ACM Conf., Feb. 4-6, 1953, Los Angeles, Calif.*, pp. 9-18; June, 1953.) Dr. Hobson draws attention to the new field of management science— the use of quantitative methods, of scientific procedures and of organized creative work toward a definite goal, by industrial management. "The really new factor in the management equation today is an increase in the rate of change to- ward greater complexity in industrial life." The author points out the role of electronic data processing in providing management with a greater volume of more accurate facts, and the role of mathematics in the analysis of those facts. The importance of human relations, and the gradual separation of management from ownership, are discussed.

R. G. Canning

BOOK REVIEWS

53-109

Proceedings of a Second Symposium on Large-Scale Digital Calculating Machinery—(*Vol. XXVI of the Annals of the Computation Laboratory of Har- vard University*, Harvard Univ. Press, Cambridge, 393 pp. +xxxviii, illus.; 1951.) In January, 1947, the Bu-

This page has been left blank in order that readers may mount all reviews on cards.

— *The Editor*

eau of Ordnance of the United ;tates Navy and Harvard University to- ;ether sponsored a *Symposium on Large- cale Digital Calculating Machinery* vhose proceedings were published in an arlier volume (XVI) of the *Annals*. A econd similarly sponsored symposium vas held at Harvard University on Sep- ember 13-16, 1949. The volume reviewed ere is a complete record of the 38 cientific papers presented at the econd symposium, the opening and anquet addresses, and the names of he more than 700 participants. Both the eneral and the specific application of igh speed automatic digital computers eceived extensive treatment at the ymposium. In his discussion of the role f automatic computation in theoretical hysics, W. L. Furry opens with a remark n the early extreme attitude of physi- ists, who felt that it had no place at ll. His hope that this attitude may be lecreasing in prevalence is partially ealized by at least four papers of direct alue to the theoretical physicist. H. T. Engstrom discusses the over-all effective ise of computing machines, illustrating is points through a description of the roblems of air traffic control and irport time utilization. Additional dis- ussions of the general application of omputing machines to problems in pecific fields include the following: I. S. Vallarta, to the theory of primary osmic radiation; H. Feshbach, to nuclear hysics; R. D. O'Neal, in aero-dynamic esearch; E. T. Welmers, to aircraft lynamics; M. Muskat, in research of the il industry; F. Mosteller, to the social ciences; L. R. Tucker, to psychology; nd F. V. Waugh, to the science of rosperity. All these papers discuss nteresting avenues of research within heir respective fields, the exploration f which has hitherto been delayed ecause of the elaborate computations nvolved. The specific applications lescribed are many and diverse. G. W. Brown applies the theory of games to a ninimax problem which arises in connec- ion with the solution of linear systems nvolving inequalities. W. E. Milne dis- usses several numerical methods ssociated with Laplace's equation and oncludes that linear partial differential quations of second order can be suc- essfully "domesticated" with the aid f high speed machines. C. Lanczos pre- ents an iteration method for the solu- ion of the eigenvalue problem of linear perators through which an arbitrary umber of eigenvalues and eigenfunctions re obtained in a single set of itera- ions, with rounding errors "effectively ounteracted." A brief exposition on the Monte Carlo method by S. Ulam sets orth the basis of this powerful new omputation procedure. H. A. Scheraga, . T. Edsall, and J. O. Gadd, Jr., dis- uss the double refraction produced in a iquid containing asymmetric molecules vhen a velocity gradient is set up in he liquid. The paper includes a computed table of the extinction angle as a function of the ratio of velocity gradient to rotary diffusion constant, for various values of axial ratio. The computation of L shell internal conversion is discussed by M. E. Rose. G. R. Stibitz describes a statistical method, similar in some fundamental respects to the Monte Carlo method, which he applies to a dynamic tester incorporating a servo motor impulsed instantaneously every sixtieth of a second. The application of his statistical method to a determination of servo behavior is described in considerable detail, and the need for an automatic calculator is made clear. A first attempt to solve the whole aerodynamic problem of combustion is presented by H. W. Emmons. The complete Seventh Session was devoted to the economic and social sciences. It includes papers by W. W. Leontieff on the dynamic analysis of economic equilibrium, H. Chernoff on econometric problems, and W. J. Crozier on physiology. Crozier touches lightly on the analogy between neural processes and computer circuit operation. In a paper dealing with mathematical methods in machines, D. H. Lehmer discusses discrimination criteria used by machines to choose between alternative courses of action, the use of subroutines, the application of random numbers generated within the machine itself during the solution of a problem, the limitations of machines and the impact of automatic high speed calculators on mathematics itself. C. C. Bramble presents an empirical study of the effects of rounding errors, illustrating some of the pitfalls usually ignored. The remaining papers are concerned with machines themselves rather than with applications. Several machines are described in considerable detail: the Harvard Mark III, by B. L. Moore; the Bell Laboratories Model VI, by E. G. Andrews; the Raytheon Computer, by R. M. Bloch; the General Electric Computer, by B. R. Lester; the 603-405, by W. W. Woodbury; and the computer of L'Institut Blaise Pascal, Paris, France, by L. Couffignal (in French). The dinner address by W. S. Elliott delineates developments in England (up to 1949) in the designs of computing machines and components. Highlights of these papers are the Harvard coding machine, the "higher intelligence" of subroutines in four levels in the Bell machine and the self-checking Raytheon number-code. The 603-405 is clearly the forerunner of the IBM Card Programmed Calculator. Semi-automatic instruction for computers is described in detail by H. D. Huskey in connection with the Zephyr under construction at the Institute for Numerical Analysis. A paper by G. W. Patterson is a first attempt to apply logical syntax to both the design and the use of calculating machines. The organization of the computation facilities at M.I.T. is presented by J. W. Forrester. The remaining five papers are concerned with computer components. J. P. Eckert, Jr., presents the dot-circle method of electrostatic storage on the phosphor of a cathode-ray tube. Photographs of a prototype CRT memory unit are included. R. S. Julian and A. L. Samuel describe a specially designed cathode-ray tube incorporating a metal plate ahead of the phosphor, to be employed as a generator of the horizontal (or vertical) deflection voltage used with electrostatic storage tubes. Two such tubes can be used to control beam positioning in any number of slave cathode-ray tubes. The SE256 Selection Tube is described in detail by J. Rajchman; a complete description of the writing, reading, and storing operations is included. W. D. Woo gives a qualitative description of the operation of digital "delay lines" employing only magnetic toroids and crystal diodes; operating characteristics and pictures of a working unit are presented. J. R. Bowman suggests several possible applications of electrochemical units as computing elements. In spite of the many aspects of the digital computer field, the Symposium succeeded in presenting an almost complete picture of the state of the field at that time. The Harvard Computation Laboratory is to be congratulated for its efforts in presenting the full text of all but one paper. A study of the Proceedings will reward all who are interested in digital computing machines and their applications.

Courtesy of *Review of Scientific Instruments*.

Morris Rubinoff

53-110

The Preparation of Programs for an Electronic Computer—M. V. Wilkes, D. J. Wheeler, and S. Gill. (Addison-Wesley Press, Inc., Cambridge, 167 pp.; 1951.) There have been a number of publications which treat the subject of coding as an adjunct to the description of a particular machine. In addition, there has been at least one privately circulated publication which discusses the planning of problems for automatic calculators. However, this is the first published book devoted exclusively to the methods of preparing programs for an automatic digital calculating machine. Although these methods are described in terms of the code of orders used in the Electronic Delay Storage Automatic Calculator (EDSAC) at the University of Cambridge, England, they are clearly applicable to many other large-scale calculators. It should probably first be pointed out that there are two conflicting attitudes regarding the storage of instructions and numbers within a calculator. On the one hand, the separationists advocate that instructions and numbers be stored in two logically and electronically distinct memory units; they maintain that in such a machine the preparation of programs and the use of library subroutines are simple, straightforward procedures. On the other hand, the

This page has been left blank in order that readers may mount all reviews on cards.

— *The Editor*

onsolidators advocate that only one nemory unit be provided within which nstructions and numbers may be stored ndiscriminately; they maintain that such machine permits greater flexibility in reparing a program. The authors make it lear at the outset that they belong to he latter school. Their book describes echniques made feasible by the com- ined memory unit by means of which the abor required to prepare programs is ubstantially reduced through the use of comprehensive set of library sub- outines. In Chapter 1 the EDSAC code f 18 orders (for internal operations) is lelineated. The conventional use of the onditional order to transfer control from ne section of the program to another is lescribed by example. Additional ex- amples show how a sequence of orders nay be designed to initiate a different set of calculations each time the sequence is repeated. The key to the method is the inclusion within the sequence of a subgroup of orders which modify other orders within the same sequence. Chapter 2 deals with the orders by which words are transferred from the external store (five-hole punched tape) into the memory unit. Considerable flexibility is provided through a number of initial orders, pseudo-orders, and control combinations. The initial orders are used to specify the memory location of operands where the location is purposely incompletely specified in a library subroutine. The control combinations enable the operator to direct the manner in which the transfer is executed. Chapter 3 presents the principles involved in preparing an EDSAC subroutine. In Chapter 4 the current library subroutines are described; they include trigonometric functions, quadrature by several formulas, integration of ordinary differential equations, complex numbers, and floating point computations. The short Chapter 5 lists a number of points to be checked in proofreading of programs. It is EDSAC experience that mistakes in programming "are much more difficult to avoid than might be expected." The remainder of the book, devoted primarily to a description of the use of EDSAC, presents minutely detailed examples of actual problems and complete specifications of numerous library subroutines. The book includes a Preface by the authors, a Foreword by D. R. Hartree, and five appendices giving EDSAC keyboard code symbols and additional coding details. Courtesy of *Review of Scientific Instruments.*

M. Rubinoff

INSTITUTIONAL LISTINGS (Continued)

LIBRASCOPE INCORPORATED
1607 Flower Street, Glendale 1, California

Analog and Digital Computers for Industrial Application; Analog Components

MAGNETICS RESEARCH COMPANY
142 King Street, Chappaqua, New York

Magnetic Shift Registers, Magnetic Switching Systems, Pulse Transformers

MID-CENTURY INSTRUMATIC CORP.
611 Broadway, New York 12, N. Y.

Analog Computers - Electronic Function Generators - Recorders - Servomechanisms

THE J. M. NEY COMPANY
72 Elm Street, Hartford, Connecticut

Precious Metals including Contacts, Slip Rings, Assemblies, Fine Resistance Wire

GEORGE A. PHILBRICK RESEARCHES, INC.
230 Congress St., Boston 10, Mass.

Electronic Analog Computing Components for Mathematical or Dynamic Applications

POLYTECHNIC RESEARCH & DEVELOPMENT CO., INC.
55 Johnson Street, Brooklyn 1, New York

Magnetic Amplifiers for Servo Systems, Voltage Regulators, Speed Regulators

POTTER INSTRUMENT COMPANY, INC.
115 Cutter Mill Road, Great Neck, N. Y.

Flying Typewriter, Random Access Memory, Mag. Tape Handler, Data Handlers

RAYTHEON MANUFACTURING COMPANY
Waltham 54, Massachusetts

Computer Components, Computing Service, Germanium Diode, Transistor, Recording Tube

REEVES INSTRUMENT CORPORATION
215 East Ninety-first St., New York 28, N. Y.

Electronic Analog Computers - Servomechanism Components - Resolvers - Gyros - Gears

TECHNITROL ENGINEERING COMPANY
2751 No. Fourth St., Philadelphia 33, Pa.

Digital Computers, Memories, Pulse Transformers, Delay Lines

TELECOMPUTING CORPORATION
133 E. Santa Anita, Burbank, California

Engineering Computing Service and Automatic Data Reduction Instruments

THE TELEREGISTER CORPORATION
157 Chambers Street, New York 7, N. Y.

Development - Data Handling and Inventory Systems - Digital and Analog Computers

The charge for an Institutional Listing is $20.00 per issue or $60.00 for four consecutive issues. (The number of characters, including spaces, is limited to eighty for the company name and address, and eighty for the products and services.)

Applications for Institutional Listings and checks (made out to the Institute of Radio Engineers) should be sent to Gerhard Walter, IBM Engineering Laboratory, Box 390, Poughkeepsie, New York.

INSTITUTIONAL LISTINGS

The IRE Professional Group on Electronic Computers appreciates the support given by the organizations listed below. The listing of products and services is limited in length and therefore is not necessarily all-inclusive.

(Please see inside back cover for additional listings.)